11037

OPTICAL SYSTEM

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Results of the Optical Survey.

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OPTICAL SYSTEM

LETTER AND SPECIFICATION

BID PACKAGE

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APPENDIX

CLASSIFICATION OF PHOTOGRAPHIC LENS TYPES *

The classification is based on the number of components in the lens, assuming that most photographic objectives fall into one or other of the following six broad groups:

Singlet (single component with exterior stop) (Types *A*, *B*)

Duplet (two similar components about a central stop) (Types *D*, *E*, *F*)

Triplet (three airspaced components) (Types *G*, *H*, *J*, *K*)

Quadruplet (four airspaced components) (Types *L*, *M*, *N*)

Petzval (two dissimilar thin positive components widely separated) (Type *P*)

Telephoto (widely separated positive and negative components) (Type *T*)

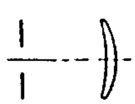
It is surprising to find that perhaps 90 percent of all photographic objective designs do fall into the above simple classes. Furthermore, many of the remaining 10 percent of doubtful or borderline cases can usually be classified after a study of the published description of the design in the patent specification or elsewhere.

It is, however, useful to establish a "miscellaneous" classification for occasional odd types that bear no relation to any of the well-established classes. Also a few other special types such as reflecting systems, zoom lenses, anamorphosers, condensers, and viewfinders have been given distinguishing type letters that are outside the main classification given above.

Plan of the Classification

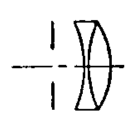
A. Single Lenses

Front or rear single landscape lenses with a stop separated from the lens.



B. Singlet Lenses, compound

Front or rear cemented (or closely airspaced) achromatic lens with an exterior stop. These systems are not intended to be used in pairs with a central stop, and are normally not spherically corrected.



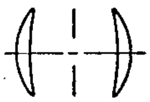
(The *B* type may be used to include telescope objectives if it is desired to do so.)

*From R. Kingslake, "A Classification of Photographic Lens Types," *J. Opt. Soc. Am.*, 36, 251 (1946).

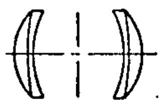
C. *Condensers*

D. *Duplets, symmetrical, not spherically corrected*

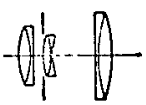
This class contains systems comprising two identical or closely similar singlets, symmetrically arranged about a central stop. It also includes the very old types consisting of three thin separated components, not spherically corrected.



D—(a) Simple Periscopic lenses.



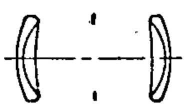
D—(b) Achromatized systems.



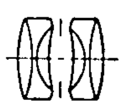
D—(c) Triplets, not spherically corrected.

E. *Duplets, symmetrical, spherically corrected and achromatic*

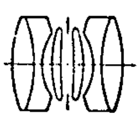
This group comprises symmetrical or almost symmetrical "double objectives," in which each half consists of a spherically corrected single cemented or closely airspaced unit.



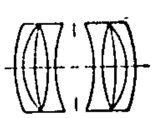
E—(a) Two similar cemented doublets.



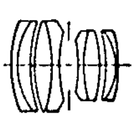
E—(b) Two similar cemented triplets.



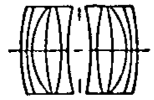
E—(c) Two similar triplets including narrow airspaces.



E—(d) Two similar cemented quadruplets.



E—(e) Two similar quadruplets with airspaces.

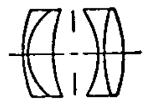


E—(f) Two similar cemented quintuplets.

E—(g) Others.

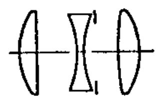
F. *Duplets, unsymmetrical*

This class contains spherically and chromatically corrected duplets of which the two halves are decidedly dissimilar to one another.



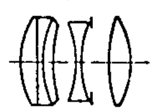
G. *Triplets, simple*

These lenses contain three single air-spaced elements, positive outside and negative inside.

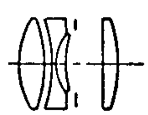


H. *Triplets, compound, i.e., containing one or more compound components*

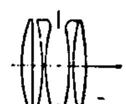
Here *l* refers to a single element and *c* to a compound component. The compound components generally comprise one or more positive and negative elements cemented together or closely air-spaced.



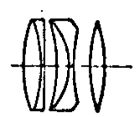
H—(a) Components c-l-l.



H—(b) Components l-c-l.



H—(c) Components l-l-c.



H—(d) Components c-c-l.

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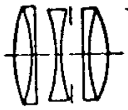
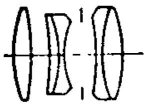
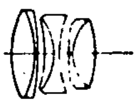


H—(e) Components c-l-c.



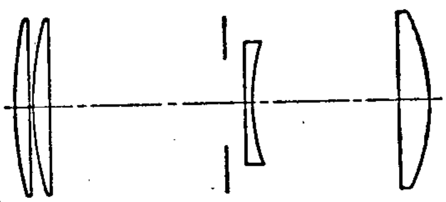
H—(f) Components l-c-c.



H—(g) Components c-c-c.

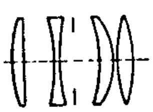
J. Triplets, divided, i.e., containing one or more divided components

In this group we find triplets of the *G* type in which one or more of the elements has been divided into two air-spaced elements of the same sign as the original element.



J—(a) Front element divided. See also Type K, below.

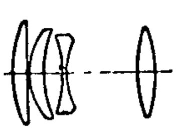
J—(b) Middle element divided. These are included under Type L, below.



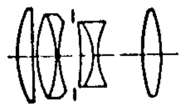
J—(c) Rear element divided.

K. Triplets, with an additional meniscus component in the front airspace

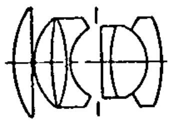
This class includes so many important modern objectives that we are justified in regarding it as a separate type, not merely a modified triplet as in class *J—(a)* above.



K—(a) The lenses in this group comprise four single elements, the second being meniscus and the third negative.



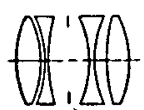
K—(b) Similar to K—(a) above, but having any or all of the four components compounded or split.



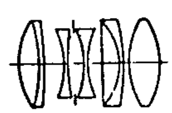
K—(c) Systems of this same type in which the second and third components are cemented together, with or without another glass element between them. Thus, in this type, the objective contains two positive exterior components with a thick meniscus-shaped negative component placed between them.

L. Quadruplets

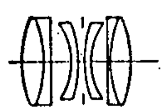
This class contains objectives having four airspaced components, in the order *plus—minus : minus—plus*, the inner negative components being either biconcave or meniscus with convex faces towards the stop.



L—(a) Four simple elements, with biconcave flints.



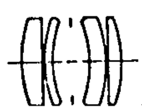
L—(b) As in L—(a), with some components compound or divided.



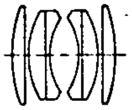
L—(c) One or both of the negative components is a meniscus, with the convex surface facing the stop.

M. Quadruplets, meniscus

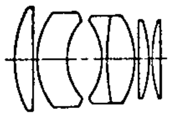
These are similar to the *L* type, but the inner negative components are meniscus-shaped and concave to the stop.



M—(a) Four single elements.



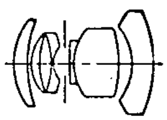
M—(b) One or both negative components cemented.



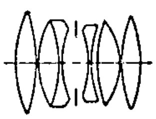
M—(c) As in M—(b), with the rear positive component divided.

N. Quadruplets, unbalanced

Here the components are not in the normal order; or the lens does not fall into either the *L* or *M* type.



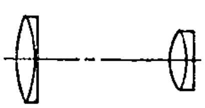
N—(a) Components in the order plus—minus : plus—minus.



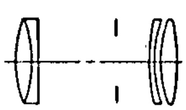
N—(b) Hybrid objectives in which one half is of the L-type and the other half of the M- type.

P. Petzval and Projection Types

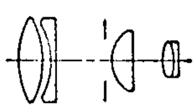
Two thin positive components widely separated, normally working at high aperture over a narrow field.



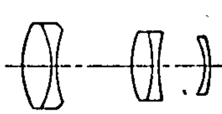
P—(a) Two separated cemented doublets.



P—(b) Like P—(a), with one or both doublets air-spaced, or one or both doublets replaced by single elements.

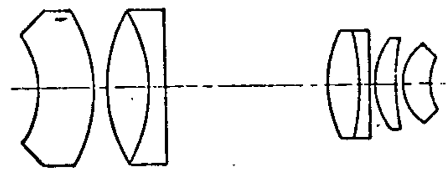


P—(c) More complicated types.

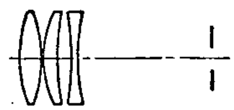


P—(d) With a field flattener.

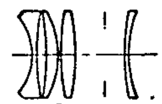
Q. Miscellaneous



Q—(a) Microscope objectives.



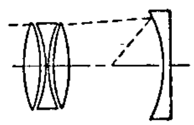
Q—(b) Profile projectors.



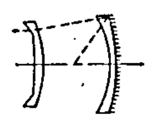
Q—(c) Unclassified photographic objectives.

R. Mirror Lenses

This class contains systems involving reflecting surfaces in addition to refracting surfaces.



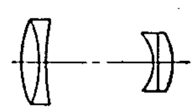
R—(a) Mirror-lens photographic objectives, using only spherical surfaces.



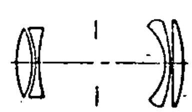
R—(b) Mirror lens systems involving aspheric surfaces (including Schmidt systems).

T. Telephoto Systems

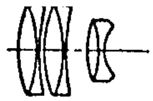
A telephoto lens is one in which the distance from the front vertex to the focal plane is less than the focal length. This result is achieved by means of a positive front member widely separated from a negative rear member.



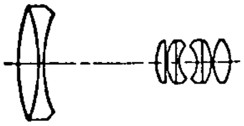
T—(a) Two thin cemented components, positive and negative, widely spaced.



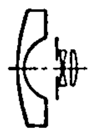
T—(b) Like T—(a), but one or both components airspaced.



T—(c) More elaborate systems.



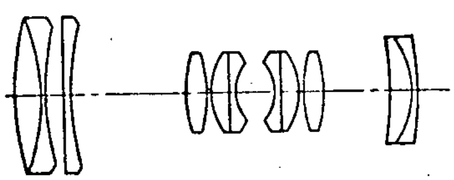
T—(d) Reversed Telephoto systems. In these the negative member is in front, and the back focus is equal to or greater than the focal length.



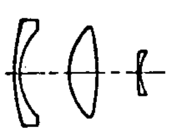
T—(e) Sky lenses. In these a field of 180° is covered, by the use of a highly distorting reversed telephoto construction.

U. "Zoom" Lenses

These are lens systems of continuously variable focal length, in which the image is held constantly in focus by mechanical means.



U—(a) Complete zoom lens systems.

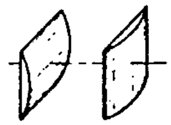


U—(b) Afocal zoom attachments to be added in front of a camera lens.

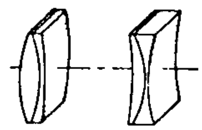
V. Viewfinders and Camera Rangefinders

W. Anamorphic Systems

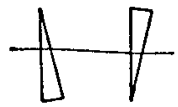
These are photographic lens systems intended to give a greater magnification in one meridian than in the other, which effect may be produced either by cylindrical lens surfaces or by refracting prisms. This class does not include sound optics or scanning units (see *Z*).



W—(a) Complete anamorphic lens systems, using cylindrical lenses.



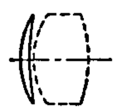
W—(b) Afocal anamorphic attachments, using cylindrical lenses.



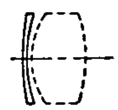
W—(c) Anamorphic attachments, using prisms.

X. Lens Attachments

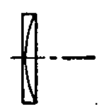
(excluding zoom or anamorphic attachments)



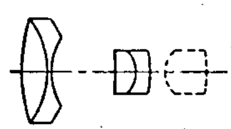
X—(a) Positive or "close-up" attachments.



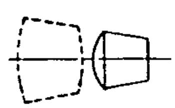
X—(b) Negative or "distance" attachments.



X—(c) Soft focus, diffusing, and chromatic attachments.



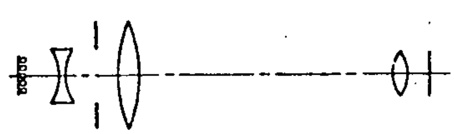
X—(d) Afocal attachments to change the equivalent focal length of a lens.



X—(e) High aperture rear attachments.

Y. Eyepieces and Loupes

Z. Miscellaneous Systems



Z—(a) Systems for recording, reproducing, and printing sound tracks on film; and scanning systems of all kinds.

Z—(b) Other systems.

Examples of lenses classified according to this method are given below.

Lens	*Maker*	*Classification*
Acomar	Rüo Optik	H—(c)
Actinar	Steinheil	G
Aeroplan	Staley	E—(b)
Aerotar	Goerz	E—(b)
Akmar	Friedrich	E—(b)
Amatar	Zeiss	E—(b)
Angulon	Schneider	E—(b)
Anticomar	Plaubel	G, H—(c)
Apotar	Agfa	G
Apotar	Rietzschel	E—(b)
Aristoplan	Meyer	G
Aristostigmat	Meyer	M—(a)
Artar	Goerz	L—(a)
Aviar	Taylor-Hobson	L—(a)
Avus	Voigtländer	H—(a)
Avuskop	Voigtländer	G
Baltar	Bausch & Lomb	M—(b)
Bausch & Lomb Kodak Anastigmat	Bausch & Lomb	H—(c)
Biogon	Zeiss	N—(a)
Biotar	Zeiss	M—(b)
Biotessar	Zeiss	H—(e)
Bystigmar	Beck	E—(d)
Caleinar	Rüo Optik	K—(a)
Cassar	Steinheil	G
Celor	Goerz	L—(a)
Chloroplast	Staeble	M—(a)
Claron	Schneider	E—(c)
Collinear (Kollinear)	Voigtländer	E—(b)
Conastigmat	Contessa-Nettel	G
Convertible Doublet	Ross	E—(d)
Cooke Triplets	Taylor-Hobson	G
Cooke Convertible Anastigmat	Taylor-Hobson	E—(e)
Cooke Distortionless Telephoto	Taylor-Hobson	T—(c)
Cooke-Kodak Anastigmat	Taylor-Hobson	G
Cooke-Varo	Taylor-Hobson	U—(a)
Corygon	Friedrich	G
Culminar	Steinheil	H—(a)
Culminar Enlarging	Steinheil	H—(c)
Dagor	Goerz	E—(b)
Dallon	Dallmeyer	T—(a), T—(b)
Detektiv-Aplanat	Ernemann	E—(a)
Dialyt	Rietzschel	L—(a)
Dialytar	Laack	G, H—(c), L—(a)
Dogmar	Goerz	L—(a)
Dominar	Ica	H—(c)
Doppelanastigmat, Ser. IIa	Goerz	E—(f)
Doppelanastigmat, Ser. IIb	Goerz	L—(a)
Doppelanastigmat, Ser. III	Goerz	E—(b)
Doppelanastigmat Pa-De	Dette	M—(a)
Doppel-Polynar	Laack	E—(a)
Dynar	Voigtländer	H—(e)
Eistal, Ser. VII B	Taylor-Hobson	M—(a)
Elmar	Leitz	H—(c)
Ernon f/3.5	Ernemann	H—(c)
Ernon f/6.8	Ernemann	E—(b)
Ernoplast	Ernemann	H—(c)
Ernostar f/2 and f/1.8	Ernemann	K—(b)
Ernotar	Ernemann	H—(c)
Eurygon	Rodenstock	G
Eurygraphe, Ser. IV	Berthiot	E—(b)
Eurynar	Rodenstock	G, L—(a)
Flor f/2.8	Berthiot	M—(b)
Flor f/3.5, f/4.5	Berthiot	H—(c)
Frontar	Goerz	B
Glaukar	Busch	G
Glyptar	Busch	H—(c)
Gotar	Goerz	L—(a)
Hekistar	Rüo Optik	G
Hektor	Leitz	H—(g)
Heliar	Voigtländer	H—(e)
Heligonal	Rodenstock	F
Heliostigmat	Voigtländer	H—(a)
Helomar	Voigtländer	G
Hypergon	Goerz	D—(a)
Igestar	Agfa	G
Iricentor	Rüo Optik	E—(b)

Lens	*Maker*	*Classification*
Isconar	Schneider	M—(a)
Kalostigmat	Goerz	L—(a)
Kataplast	Staeble	G
Kino-Plasmat	Meyer	L—(c)
Kodak Anastar	Eastman	H—(c), K—(a)
Kodak Anastigmat	Eastman	G, H—(c), L—(a), T—(a)
Kodak Anaston	Eastman	G
Kodak Ektar	Eastman	H—(c), H—(e), L—(a), M—(a), M—(b)
Kodak Enlarging Ektanon	Eastman	G, H—(c), L—(a)
Kodak Enlarging Ektar	Eastman	H—(e), L—(a)
Leukar	Busch	E—(b)
Linear	Rietzschel	E—(d)
Lineoplast	Staeble	F
Lustrar f/4.5	Wray	L—(a)
Magnar	Zeiss	T—(a)
Makinar	Plaubel	E—(b)
Manar	Demaria-Lapierre	H—(c)
Maximar	Ica	E—(b)
Metrogon	Bausch & Lomb	M—(a)
Mytal	Taylor-Hobson	G
Neostigmar	Beck	G
Nettar	Contessa-Nettel	G
Nostar	Ica	G
Novar	Zeiss	G
Olor	Berthiot	H—(c)
Omnar	Busch	M—(a)
Opic	Taylor-Hobson	M—(b)
Oppar	Agfa	H—(c)
Orthometar	Zeiss	E—(c)
Orthostigmat (old)	Steinheil	E—(b)
Orthostigmat (new)	Steinheil	E—(c)
Oxyn	Voigtländer	H—(e)
Pantachar	Astro	J—(c)
Pantar	Goerz	E—(d)
[illegible]	Dallmeyer	H—(e)
Perigraphe	Berthiot	E—(b)
Planar	Zeiss	M—(b)
Plasmat	Meyer	E—(c)
Polyxentar f/6.8	Laack	E—(b)
Polyxentar f/4.5	Laack	E—(c)
Primoplane	Taylor-Hobson	G
Protar, Ser. V	Zeiss	F
Protar, Ser. VIIa	Zeiss	E—(d)
Protoplast	Staeble	E—(b)
Quinar	Steinheil	H—(e)
Radionar	Schneider	G
R-Biotar	Zeiss	P—(c)
Rectagon	Goerz	M—(a)
Regulyt	Laack	G
Septac	Dallmeyer	M—(b)
Serrac	Dallmeyer	H—(c)
Skopar	Voigtländer	H—(c)
Sky Lens	Beck	T—(e)
Solar	Reichert	L—(a)
Solinar	Agfa	H—(c)
Solinear	Rietzschel	H—(c)
Sonnar	Zeiss	K—(c)
Stigmar	Busch	E—(c)
Summar	Leitz	M—(b)
Supar	Wray	G
Super Dagor	Goerz	E—(b)
Symmar	Schneider	E—(b)
Syntor	Goerz	L—(a)
Tachar	Astro	J—(c)
Tachon	Astro	N—(b)
Telecentric	Ross	T—(c)
Tele-Anastigmat	Rüo Optik	T—(c)
Tele-Dynar	Voigtländer	T—(c)
Telegor	Goerz	T—(a), T—(b)
Tele-Peconar	Plaubel	T—(a)
Telephoto, Ser. VIII	Taylor-Hobson	T—(a)
Tele-Tessar	Zeiss	T—(a), T—(b)
Tele-Xenar	Schneider	T—(c)
Telikon	Zeiss	T—(b)
Tenastigmat	Goerz	L—(a)
Tessar	Zeiss	H—(c)
Topogon	Zeiss	M—(a)
Trianar	Krauss	G
Trilinear	Rietzschel	G
Trinar	Rodenstock	G

Lens	Maker	Classification
Trinastigmat	Contessa Nettel	G
Trioplan	Meyer	G
Triotar	Zeiss	G
Triple-Orthar	Plaubel	E—(b)
Triplet	Zeiss	G
Trylor	Roussel	G
Tular	Rüo Optik	G
Turner-Reich	Gundlach	E—(f)
Unar	Zeiss	N—(b)
Unilite	Wray	M—(b)
Unofokal	Steinheil	L—(a)
Voigtar	Voigtländer	G
Wide Angle Xpres	Ross	E—(c)
Xenar	Schneider	G, H—(a), H—(c)
Xenon f/1.5	Leitz	M—(c)
Xenon	Schneider	M—(b), M—(c)
Xpres f/2.9, f/3.5, f/4.5	Ross	H—(c)
Xpres f/1.9	Ross	M—(b)
Zeiss-Kodak Anastigmat	Bausch & Lomb	H—(c)

JOB 302

OPTICAL SUBCONTRACT

SPECIFICATION OS-2-302-15/18

VENDOR EVALUATION

STAT

Optical designer in plant	4	1	3	4	4	4
Computer in plant for optical design	2	1	1	1	3	4
Mechanical designer in plant	3	4	1	3	1	5
Electrical designer in plant	1	4	1	1	1	5
Drafting facility in plant	1	5	1	3	1	5
Plant space available for addn'l work	1	1	1	5	1	5
Fabrication facility available for optics	2	1	1	4	1	5
Fabrication facility available for mechanisms	2	3	2	3	1	5
Optical consultant available	5	5	1	1	1	5
Laboratory & test facilities available	2	2	1	5	3	5
Previous photogrammetric design experience	4	5	3	5	5	5
Project oriented - Report making capability	2	5	3	5	2	5
Comprehension of job scope	3	5	2	5	4	5
Interest & cooperative attitude	2	5	4	3	3	5
Time schedule for design performance	4	2	4	2	2	4
Proximity to NRI	4	3	2	2	3	1
Impression of overall competence	2	4	3	5	3	5
	2.6	3.3	2.0	3.4	2.3	4.6

RATING - Basis for Scoring

1. Worst possible.
2. Less than acceptable - Poor.
3. Acceptable - Average.
4. More than acceptable - Good.
5. Best possible.
0. No technical information.

STAT

Evaluation of Design Capability:						
Objective lens system	0	3	3	2	0	5
Zoom lens	2	4	4	4	0	4
Anamorph lens	2	2	4	4	0	4
Image rotator	3	3	4	3	0	4
Corner reflectors	0	0	0	2	0	4
Beam splitters	0	0	0	0	0	4
Optical switching	4	2	0	4	0	4
Eye pieces	0	0	2	4	0	4
Reticle system	3	4	3	4	0	4
Illumination system	2	3	2	4	0	4
Illumination source	3	3	2	4	0	3
	1.7	2.2	2.2	3.2	0.0	4.0
Percent of Possible	47%	60%	45%	68%	31%	87%
GRAND AVERAGE	2.3	3.0	2.3	3.4	1.6	4.3
Substantially capitalized	4	5	2	5	4	5
Fixed price contract, or other	3	5	5	3	2	5
Price quoted	4	1	5	3	3	5
Cost of monitoring the project	1	5	2	5	2	2
	3.0	4.0	3.5	4.0	2.8	4.3

[redacted] STAT

SUMMARY OF VISIT

The visit to [redacted] took place on June 1 and 2, 1967. STAT
[redacted], as it is presently constituted, is a merger of several optical STAT
manufacturing organizations and is at present the largest optical
manufacturer [redacted] It has 1700 employees and four plants. The STAT
technical department in which our Stereo Comparator job would be
performed comprises 85 employees and encompasses optical design,
physics and mechanical engineering, electronic engineering, drafting
and various optical, mechanical and electronics technical development
shops.

The founding company was known [redacted] STAT
[redacted] The second company involved was [redacted] STAT
[redacted] An additional optical manufacturing STAT
firm is presently being brought into the combine; its name was given
rather under the table as apparently some aspects were not yet fully
consumated. It was referred to as the [redacted] I was not STAT
in a position to inquire deeper; however, I did learn that they were manufacturers of microscopes and were experts in the precision surface working
of optical glass. The design work for our project would be done at the
[redacted] plant and all the engineering talents were in this STAT
particular plant. The plant as a whole was large and was well instrumented
and equipped. The manufacturing facilities appeared old; however, the
rotating glass grinding equipment was obviously very expensive and
presented a very impressive layout. (This was distinctly different from
the other plants which I have reviewed in connection with this optical
survey.) [redacted] was by far the largest firm and with the greatest amount STAT
of talent and technical capability that I had seen during this survey. It
was clear that the Stereo Comparator project would hardly effect the

operations of this large company. It would certainly not overload their capability or their capacity.

Their equipment included two computers, a BULL recently purchased from General Electric, and an IBM 1130 which was a much more elaborate machine. [redacted] uses these computers for performing optical design and their own optical systems work. STAT

In addition, [redacted] regularly consults a [redacted] of one of the Paris optical design schools for what they call "optimizing their designs". This man works as a consultant only for the purpose of "optimizing". STAT

[redacted] was present at most of the technical sessions with the [redacted] organization. My tactical arrangement with him was that I would first ask questions and receive the answers, at which time [redacted] would make his personal evaluation of the answers. Then, upon completion of my questions, he would begin his own questioning, and review any technical points which he felt had been either overlooked or mishandled by the [redacted] organization. STAT STAT STAT STAT

At the end of the review I requested from [redacted] a statement as to his impression of [redacted] as they related to our project. His answer was absolutely and unqualifiedly affirmative, in that he felt [redacted] could do all the work that was necessary for our project. He admitted being very impressed with their technical achievements, capabilities and their manufacturing plant and their scientific approach to optics design and manufacture in general. STAT STAT STAT

It had become clear to me in making the optical survey as a whole that most of the companies in the U.S. which I had visited were very inadequately equipped with personnel for optical design work. Their capability was shallow and those companies that offered the capability usually consisted of one person who was overworked and had neither the inclination nor the time to get involved properly in our effort. This situation was certainly not true [redacted] They seemed eager to do STAT the work. I suspect that due to their mergers [redacted] is supplied with STAT more personnel than they are able to use and they do not want to start laying people off. This was not confirmed but merely a personal opinion.

I was taken under the wing of [redacted] the STAT technical director. He spoke English in a very elementary way; that is, he did not know the technical equivalents for most of the optical techniques. However, he was able to comprehend the general meaning of my English questions, which I amplified by drawing and with [redacted] assistance. My method of discussion was to not let go STAT a point until it was clearly demonstrated that the [redacted] people under- STAT stood the question and that [redacted] understood their answer. STAT

The General Manager [redacted] as head STAT of the technical department, reported directly to him. The technical department was divided into a number of bureaus but only the few that I was directly concerned with were reviewed, since time was limited. [redacted] was the head of the Studies and Optical Calculations STAT department. [redacted] was the director of the Bureau of Studies. STAT [redacted] was the head of the Electronic Laboratory. [redacted] was the STAT head of the Optical Laboratory.

[redacted] had 3 assistants, [redacted] STAT [redacted] spoke English fairly well without STAT a heavy French accent and would be useful as a contact in telephoning the plant. She appeared to be quite competent in what one could call "every-day-English".

[redacted] was the engineering assistant in the Bureau of Design Techniques. [redacted] was the assistant to [redacted] STAT STAT STAT

The people named above were the key staff members. Being interested in meeting their staffs, I would be taken to a room where from 4 to 10 people would be introduced to me as assistants to so-and-so with title and responsibilities enumerated. There were too many names to record. The impression that I received from these introductions and questionings was one of extreme technical depth. [redacted] during the course of the visit explained that he had worked closely with photogrametric instrumentation design. STAT

OPTICAL SYSTEM REVIEW

1. Objective Lens

The objective lens would have an aperture of F1.3 with a focal length of 80 mm. The space between the objective lens and the film plane would be 10 mm. The objective would have a fixed magnification and the zoom system 10:1 range would be extended by a switching device installed after the zoom. The switching device would have a 2X factor, thus giving the coverage of 20X with a 10:1 zoom ratio.

The depth of focus of the objective system would be $\pm$ 1 micron maximum.

[redacted] proposed design for the fine focus of the objective would consist of a set of flexing beams or torque beams. By this technique, the beams would present a parallelogram to the optical movement; thus there would be no backlash or image wander due to the fine focusing. STAT

2. <u>Beam Splitter for Reticle Injection</u>

[redacted] favored a dialectric-type coating on a front surface mirror for the beamsplitter. They stated that a penta prism system would not be necessary as the system between the reticle, the image splitter and the objective lens can be made mechanically rigid and thus the penta prism would add nothing to the system. STAT

3. <u>Zoom System</u>

The zoom system is required to be an afocal system; hence the light in and out of the zoom section must be fully collimated with the light paths parallel. [redacted] proposed to use a 10:1 zoom for best image quality with a focal length changing from 12 to 120 millimeters. They stated that the design for this presently exists. There would be less than 0.05 millimeters of optical axis translation during the zooming operation. In order to realize a 20X zoom capability a 2X optical switch would be provided in the optical path after the light beam had passed through the zoom system. The 2X optical switching would consist of a pair of lenses which would be positioned either in the light path or turned 90° out of the light path. The image wander caused by the switching in or out of this pair of lenses would be only a few per cent of the diameter of the field of view. Further note that there is no change in the relative position of the reticle and the object caused by the switching operation; since this occurs beyond the point of injection of the reticle onto the objective field of view. STAT

The length of the zoom system is estimated to be 556 mm. This is the length of the light path between the top of the zoom lens and the film plane. The length of the zoom system itself would be 30 centimeters and its diameter would be 65 millimeters. This zoom assembly was very complex compared to the zoom systems that I had seen previously. There were 12 separate pieces of glass with 3 sets of mechanical movements. I was shown an assembly drawing of the zoom optics for a 6:1 range. I also was shown 3 sets of zoom optics of the order of 8X to 10X which were for photographic cameras, for TV cameras and for photographic projectors. These zoom systems were electric motor driven and had their own transducer encoders and automatic diaphram light level controls with internal photo cells. They appeared very well made and were quite complex and compact. In addition I was shown these various lenses installed on a projector in a test room with a special test object chart consisting of a set of circles, rectangles and diagonal lines. The image was projected onto a screen where the various dimensions were checked as the device was zoomed in and out. In addition it was possible to see the change of light level between the center of the image on the screen and the outside edges. [redacted] STAT stated that this image presentation by the zoom systems was of first caliber quality.

With the particular zoom design visioned [redacted] the zoom STAT motion is not quite linear. Therefore part of the mechanical motion requires cams which will move the optical elements in relation to each other by a non-linear function. The cam will be calculated to fit the function.

The zoom assembly would be designed with a series of sleeves and a pair of helical cam slots. Each sleeve fabricated would meet a tolerance of ± .1 mm for placement of the zoom element. Where the cams are related to a surface, the helix cams would be fabricated to a tolerance of ± .001 mm.

The cam followers will consist of plastic rollers which ride in the helix slots. I noticed that a fair amount of back lash occurred in the models that I was shown and requested that one be disassembled so that I might see its construction. It was apparent upon examination that no provision for biasing the cam to eliminate backlash was included in the design. Apparently the concept was to fit the plastic rollers into the helical slots and as the helical slots were precision machined, the fitting of the assembly was considered complete and the system would be expected to maintain its required alignment for the life of the equipment.

I pointed out that this type of design (i.e. the inherent back-lash type) would not be acceptable. [redacted] engineers immediately said STAT that they would create a spring loaded design to bias the follower against the cam and against the guide slot. The guide slot was the motion producing guide slot for the optical elements.

There is no reason why a spring loaded cam follower would not be satisfactory as a means of eliminating the backlash. The models shown to me had external ring gears and the motor drives were mounted on an axis parallel to the optical axis. Each motor pinion was equipped with a friction clutch so that if the system came to end of its travel and the motor continued to run, it would merely slip against the spring load of the slip clutch. The whole device appeared very straightforward and represented, [redacted] and my own opinion, the highest quality of STAT design and fabrication.

4. The Corner Mirrors

The corner mirrors would consist of prism reflectors. They would not be coated and they would have 100 per cent total internal reflection.

5. Resolution

[redacted] engineers stated that the 1,000 line pairs per mm at a magnification of 200X would not be attainable under any circumstances. This view was based on [redacted] wide experience in the design and manufacture of zoom lenses. Their statement was agreed to by [redacted] and there was no question in my mind that these people were sufficiently expert to make such a decisive and confident stand. They stated that they could design the system for a resolution of 700 to 800 line pairs per mm. We explored the conditions under which the 1,000 line resolution and 200X would be attainable and [redacted] concluded that if the illumination spectrum could be reduced to a range of 5,000 to 5,800 A^{o} then they would expect to be able to produce a theoretical design with 1,000 line pairs per mm resolution. They stated further that in our case, with so many surfaces required by so many other optical transformations, we would be lucky to achieve 80% of the theoretical resolution in the actual installed hardware.

STAT STAT STAT STAT

A discussion between [redacted] arose on the question of the resolution at the 10X end of the magnifaction spectrum. They concluded that it would be impossible to maintain a higher resolution at one end of the instrument magnification range than at the other end, and that 5 line pairs per mm per magnification power would hold throughout the range. Hence a 50 line pairs per mm resolution at the 10X portion of the magnification.

STAT

6. Scale Switching for Zoom 2X System.

The switching system would consist of a 2X Galilean telescope located above the anamorph system, i.e. between the anamorph system and the eye pieces, in such a manner that with the telescope inserted in the optical path there would be a magnification of the optical system. With the telescope turned 90 degrees, its optical elements would be removed from the light path and therefore cause no additional change in magnification of the optical system.

7. Anamorph

The anamorph assembly proposed would have a 1:1 to 2:1 ratio and be the cylindrical lens type operated afocally, i.e. the light beams would be parallel, into and out of the anamorph system. The technique of moving the cylindrical lenses would be similar to that for the zoom system described earlier. The placement of the optical elements in the anamorph assembly would be ± 1 mm apart with a 2 degree field of view to minimize the distortion. The optical elements would be mounted in sleeves, with the sleeves fitted with helix slots and, like cams, causing the cylindrical anamorph elements to move along the optical axis. Relate to Ist

The image wander of the system would be 0.01 mm, which is similar to that obtained by the zoom system. No visible rotation of the optical path would occur as the anamorph cylindrical lenses were zoomed.

8. Field Rotation

A matching system would be provided ahead of the field rotator. Since the light beams in the optical system would not be parallel in passing through the rotator, but instead converge in the direction of eye pieces, a K prism is proposed as the rotator. The K prism is preferable to both the dove prism and the Pechon-typs prism for its greater ability to control optical aberrations.

9. Beamsplitters for Photo Cells

The beamsplitters would be optical cubes placed in the main optical path. Each optical cube would consist of a cemented pair of coated prisms. The prisms would maintain the full quality of the transmitted optical images and cementing the prisms would provide permanent life for the coated surfaces. Thus there would be no degradation of image quality with time.

10. Corner Mirror For Eye Pieces

The corner mirrors for the eye pieces would consist of prisms of the total internal reflecting type, uncoated, except for anti-reflection coating.

11. Optical Switching

Manual optical switching would be performed by using prisms. Four optical combinations would be available and a plug in arrangement would be used.

12. Eye Piece Convergence

Photogrammetric instrument eye-pieces generally converge at one meter, i.e. with an included angle of just under 1 degree, and the angle of convergence is not changed as the inter-pupilary distance is changed. A squint angle adjustment would be incorporated in the Stereo Comparator provided either by lateral displacement of the eye pieces, or through a crossed-prism pair which would adjust angle of convergence, squint angle translation, and inner pupilary translation as required. This latter system seems more complex but in reality might turn out to be simpler to design.

13. Eye Pieces

would provide an eye relief of 17 to 20 mm. The necessary apodizing would be included in the design. STAT

The exit pupil diameter at 200X magnification would be 1 mm. The exit pupil diameter would be eye limiting at 10 magnification and would be 2 mm. The larger exit pupil diameter is necessary at the 10X magnification to provide the maximum line pair per mm resolution at this range.

Probably a 2 mm diameter would not be attainable in reality, but it could be approached.

Because of the changes in pupilary diameter, the illumination condensing system must be the zoom type. Otherwise the eye piece light level would change as the magnification was changed.

The eye pieces would be of a Ploss design. These units consist of two achromatic doublets close together, plus a wide angle supplementary lens on the eye side. A choice of 10X magnification for the eye piece was considered proper and satisfactory.

Focusing of the eye pieces for aberrations in the eye would be done by separately moving each eye piece in and out and additionally, by a gauged control which would move both eye pieces together. The gauged, or dual adjustment control, would be important for refocussing as the ~~film plane shifted~~. Refocussing by separate eye piece adjustment alone would make for tedious operation of the Stereo Comparator and would seriously affect its use if the film was not perfectly flat.

[redacted] pointed out that adjusting the optical system, not STAT only the first time but in production use, would be rather difficult since the focus requirements of the reticle, the film plane and ocular problems of the eye would be interrelated. The optical system would fall out of focus with relative ease and refocussing the complete system could be difficult. Hence, there will need to be a careful written procedure available for adjusting the various focus mechanisms.

14. <u>The Reticle</u>

[redacted] proposes a reticle system that would be optically STAT complex and would essentially parallel the design of the main optical system. Thus the envisioned reticle system would begin with a light source opposite a small hole which produces the reticle image. An 80 mm focal length objective lens would next provide a parallel light path through the compensating assemblies. A 4:1 zoom lens adjacent to the 80 mm objective lens would give the required 4:1 range variation of reticle size. Following the 4:1 zoom would be the main 10:1 reticle zoom system and it would be operated by compensating servos linked to and following the requirements of the main optical path zoom system. Adjacent to the 10:1 reticle zoom arrangement there would be an optical switching device giving a 2X magnification and servo driven by the main optical path switching device. An anamorph correcting arrangement would follow next, servo driven from the main optical path anamorph. The light beam exiting from the reticle anamorph would pass through a 2 mm focal length lens system and then through a 200 mm focal length lens system from where it would enter the beamsplitter and pass into a collimated section of the main optical system.

The combination of 2 mm and 200 mm focal length lenses was chosen to reduce the sensitivity of the system to reticle image wander. This lens pair, it was stated, would give reduction in wander of the order of 100 to 1, the design objective being to hold the image wander of the reticle in the main optical light path to not more than 1/4 of a micron. [redacted] concurred with [redacted] that this design was an ingeneous and satisfactory means of compensating for reticle image wander. STAT

[redacted] stated that they did not consider an iris diaphram to be a practical method of controlling reticle size. Among the reasons given were rough metal edges and noncompatibility with the parallel path optical system envisioned. STAT

The diffraction limited reticle will be apodized in order to eliminate the first diffraction ring surrounding the reticle.

15. Light Loss in the Main Optical Path

[redacted] estimated that the light loss between film plane and eye pieces would be at least 80 to 85 per cent on a theoretical basis. They would control this wherever possible with multi-layer anti-reflection coatings. In the actual hardware, the light loss might be higher than the values given. STAT

16. Condenser System

It will be necessary for the condenser to zoom through the entire 20:1 main optical range. Therefore, a condenser system compatible with the main optical path system would have a 10:1 zoom with a 2X switching arrangement, all servo driven and following the main optical zoom optics.

17. Illumination Zoom and Anamorph System

The main illumination source would require careful filtering to eliminate infrared radiation and would need a condenser located at the lamp itself. A condenser zoom system is proposed which would have about 1/3 the diameter of that required for the main optical system. It is anticipated that the zoom length would be between 10 and 15 centimeters and its diameter about 5 centimeters. Therefore the 6-inch diameter hole provided through the granite slab would be more than adequate.

An anamorph correction was believed necessary in the condensing system to match the anamorph corrections in the main optical path. This conclusion was reached after a considerable amount of discussion between [redacted] and various [redacted] designers, and was a change from the conclusions arrived at originally [redacted] STAT STAT

18. Light Change and Illumination

[redacted] proposes to adjust the change of light level by using neutral density filters. These would be paired glass wedges functioning with opposed motion. STAT

When I initially asked [redacted] what kind of main illumination STAT
lamp they planned they stated without reservations that a quartz iodine
type with a power of 50 to 150 watts would be used. I was extremely
surprised at this choice and requested [redacted] to fully review this STAT
topic since they had apparently overlooked some of the lamp require-
ments. After considerable discussion, [redacted] realized that they were STAT
seriously underpowering the light source and began considering mercury
vapor and xenon lamps. They also began to consider for the light source
a spectrum of 5460 angstroms to 5780 angstroms or a band width of 320
angstroms. This would be in the green/yellow range. Originally we had
discussed with them an 800 angstrom bandwidth which is considerably
below the requirements of the human eye. The discussion soon became
confused with many different opinions being aired. [redacted] STAT
apparently, had come to no definite conclusion yet regarding the lamp
brightness requirement. In the interest of saving time the discussion
was dropped at this point. [redacted] agreed that they would need to STAT
consider the subject further before they could recommend a suitable
light source.

19. <u>A Question of Locating the Reticle at the Eye Piece</u>

[redacted] tentatively asked [redacted] whether the reticle STAT
could be better placed at the eye piece for reasons considered earlier in
the discussions. The [redacted] engineers emphatically insisted that the STAT
reticle should be injected immediately after the objective lens and
<u>should</u> <u>not</u> be injected at the eye pieces. [redacted] stated that they STAT
could easily maintain the spot stability as previously described and that
since the optical parts of the reticle system are small in diameter and
relatively unsophisticated, the scheme described earlier is the most

economically satisfactory, and is definitely recommended over putting the reticle elsewhere in the system.

20. General

A schedule of meetings had originally been set up at [redacted] STAT to review the mechanical and electronic aspects of their proposal. Unfortunately, an additional day or two would be necessary to cover all the topics in detail. Therefore, only a very brief interchange took place in these design areas and without significant results, except for meeting the various electronic and mechanical engineers that [redacted] proposed STAT for work on our design effort.

At this point I requested and obtained an interview with [redacted] the commercial director. [redacted] in effect, is the sales STAT manager and he would represent the commitments for [redacted] on our STAT contract. His assistant was [redacted] Both of these gentlemen STAT spoke English, but with heavy French accents.

21. Drawings

[redacted] preliminary estimates for the number of drawings STAT required on the optical design was 1,000. This was given as an outside figure but they did not think the eventual total would be much less.

[redacted] and myself retired for private discussion STAT and considered the form of the drawings to be made and to what extent [redacted] would cooperate with our American style drawing requirements. STAT The following were the points discussed and tentatively agreed to:

(a) [redacted] would produce drawings with a special title STAT block or alternative identification, on our paper; this alternative was left open.

(b) The drawings would be made to the American type of projection, i.e. third angle projection.

(c) The drawings would be dimensioned in the metric system and all the design work would be carried out using the metric system. However, all metric dimensions would show a bracket beneath giving the equivalent English decimal dimensions.

(d) On the choice of screw threads, which cannot be readily transposed between metric and English measurement systems, [redacted] stated that he would be willing to use either the English or metric thread system, whichever we desired. This I believe is a fundamental problem not yet resolved. If the hardware was to be built in Europe the metric thread would be necessary, but if the hardware should eventually be built in the U.S. the English thread system would of course be necessary. At this point I believe the only solution is to make the design the metric style and then let American companies bid on a conversion job with the understanding that the nearest equivalent English threads must be used. Eventually we would have to rework metric drawings to show the English threads if an American company should turn out to be the low hardware bidder. I personally feel that should [redacted] be awarded the design a follow-through with the hardware contract seems highly probable. Thus the idea of completing the design drawings in the metric thread system would make good sense and would minimize cost. A further consideration is that fewer drawing errors can be expected if the threads are selected by [redacted] in the metric system

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and not translated into English by them. A translation into English threads by [redacted] engineers might turn out to be disorganized for lack of familiarity with them. STAT

The conversion of metric dimensions to English dimensions in general presents no problem since it is merely an arithmetical interchange and is not materially pertinent to the design except in a limited number of situations.

(e) Component designations on the drawings would be made in European catalog numbers and additionally, wherever possible, in American catalog equivalents as alternatives. While inspecting some French servo motors and amplifiers and various catalogs related to our application, I noted that the parts were similar to their American counterparts in shape and size, and the technical detail given in the catalogs was equally similar. From this I believe that finding European or American counterparts will, in most instances, be reasonably straight forward.

22. <u>Schedule</u>

In addition to the drawing commitment, a possible schedule of interchanges was devised for this program.

[redacted] agreed to send representatives [redacted] if we so desired, STATT sometime before the end of June. These would be qualified people to negotiate a contract and would have authority to speak for [redacted] I assume that this STAT group will include the technical director, [redacted] If a contract could be STAT approved by the end of June, a second meeting would be held in Paris at the end of July.

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[redacted] pointed out that their company shuts down on July 28th for a vacation extending through August. Although the plant is idle during this period, the high IBM computer costs make it mandatory to continue optical design work involving the computer. Therefore, [redacted] is awarded a design contract, the work would continue through August despite the holiday. STAT

A third meeting would be held in Paris eight weeks after the second meeting, or the end of September, and would indicate the 3-months point of the contract. A fourth meeting held in Paris in the middle of November with [redacted] and all interested individuals from NRI Berkeley attending would represent the 5-1/2 months point of the contract. This would be a formal design review meeting at which all coarse corrections would be made. From this jpoint on there would be no time recovery in the event of design changes instituted [redacted] A fifth meeting would be held in Berkeley at the end of December, representing 7 months of the design contract. All drawings and specifications would be delivered two weeks later in Berkeley at the completion and the 7-1/2-months point of the contract. STAT

Interface information required [redacted] would be transmitted at various times as it was developed during the contract. Most interfaces would be completed by the end of September with the total completed by the middle of November. STAT

With the staff available at [redacted] I feel that the schedule proposed is realistic and nor have I reason to doubt the sincerity of the [redacted] people. They did not belittle the project in any way, or appear apprehensive of completing the project. Instead, they concluded that with their large resources, they would be able to take the difficulties in stride. STAT

[redacted] STAT

Permission was given me to visit [redacted] STAT

[redacted] STAT

[redacted], and it was currently engaged in transforming STAT stereo aerial photographs into maps by means of scriber carrying plotters on large plotting tables. There were at least six 9 x 9 inch size Presa stereo plotters and one SOM stereo comparator available. The Presa instruments had a 4 micron measuring accuracy and the SOM instrument had a 1 micron measuring accuracy. These instruments had been manufactured by [redacted] dur STAT the past 10 years and had given satisfactory results, according [redacted] STAT He spoke highly of the equipment and the service they gave, and was unable to offer any derrogatory comments, no matter how hard I pressed. Although the machines were in use, I was allowed to operate and readjust them and in general to get the feel of the instruments. Stereo vision was excellent and the controls and general arrangement of the machines were well designed from the viewpoint of human factors. In my opinion, these machines were of the hghest quality, both in design and manufacture, and such quality would be eminately suitable for our Stereo Comparator. I feel certain that machines of this caliber would be satisfactory to our customer, and on the basis of their technical and manufacturing abilities we should not hesitate to deal with the [redacted] organization. STAT

As an interesting feature, [redacted] was using dark reticle STAT spots and seemed to favor a dark spot method. I also found it simple to use, and advantageous as well. There was no need to constantly manipulate the reticle brightness control since the dark spot was satisfactory for all illumination levels of the photographic image.

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[redacted] STAT

SUMMARY OF VISIT

A meeting [redacted] was formed on May 22, 1967 STAT
which included the following people: [redacted], President of the Company; STAT
[redacted] Vice President and Director of Engineering; [redacted] STAT
Staff Consultant; [redacted] Manager Program Development; [redacted] STAT
Optical Consultant [redacted] Manager Product Development; and [redacted] STAT
[redacted] Operations Manager Electronic. STAT

[redacted] apparently was spokesman for [redacted] in all STAT
technical aspects related to our project. Their basic technical proposal
was apparently developed and written [redacted] as he was the only STAT
person familiar enough with the project to discuss it with me. My feeling
was that the [redacted] as a whole had not participated in STAT
preparing the proposal.

CONCLUSIONS REGARDING [redacted] STAT

This firm appears eager to get the job. I received the impression that the management people were very adept at working a contract to maximize the extras, in order to gain additional funds. They appeared to have no capability whatsoever in the optical area, and their capabilities in the mechanical and electronical fabrication fields appeared to be no more than ordinary or standard good shop practice. Their administration and project management areas seemed exceptionally weak and amazingly out of character with the way they had represented themselves. They discussed the possibility of follow-on hardware supply, and appeared to be more interested in this area than in loading their already over-burdened drafting room.

One of the problems in awarding the contract to [redacted] STAT would be that their personnel would get nothing out of the optical work, it going all to [redacted] Their own design, engineering and drafting areas STAT are already loaded with work. Perhaps they are really interested in the possibility of the follow-on hardware, since their model shop was vacant of work. This situation would not be conclusive to a sound working relationship during the design of the system.

OPTICAL SYSTEM REVIEW

1. Objective Lens System

The objective lens would be between 1/3 and 1/2 inch in diameter and its lower surface would be located 0.15 inches above the film plane. This is not the true objective lens element itself, but instead, the field flattening element which is immediately beneath it, lying between the film plane and the objective lens. This particular field flattener assembly

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is required in order to gain the highest magnification of the system, i.e. the 20:1 to 200:1 range. [redacted]damently insisted that there STAT was no possibility in increasing the 0.15 inch height requirement. This creates a problem [redacted] in that the vacuum hold down system STAT will have a difficult interference problem. [redacted] will need to design STAT around this particular feature since there is no alternative but to accept the height number from [redacted] STAT

An optical switching arrangement at the objective lens assembly is proposed for accomplishing the 10X to 20X power systems. This would consist of a face spline for indexing the two systems in a precise manner. The spline system will be approximately four inches in diameter and will be repeatable within on second of arc. In addition to the face spline, one of the systems will be equipped with a pair of optical wedges for locally and accurately adjusting the central alignment of that particular axis.

2. Reticle System

The normal anamorphizing of the reticle spot would be compensated by providing an additional anamorph for the reticle projector itself. This anamorph would consist of a pair of cylindrical lenses having a 2:1 ratio change. A question arose regarding the action of a diffraction limited reticle by an anamorphic lens system. [redacted] stated that STAT the diffraction limited dot along with its rings (or any other "junk") will retain its circular cross-section while passing through an anamorph optical system. Once the dots of the reticle have become large enough to overcome diffraction limiting, they will then take on the appropriate sausage shape caused by the anamorph. My question concerning what happened to the rings and "junk" that surround the diffraction limited reticle dot was answered with the information that they stay round and do not elongate or otherwise appear sausage shaped.

Variation in size of the reticle will be covered by the 4:1 zoom system with mechanical compensation. The spotsize would be selected manually and maintained by an iris diaphram operating in conjunction with the main optical path zoom system. By servo control the main zoom system would adjust the blades of the iris diaphram in a 10:1 ratio range so that spot size would remain the same throughout the zooming of the optical system. A sufficient number of iris blades would insure the spot remaining substantially circular.

Access will be necessary to the reticle assembly, to the zooming motor drives and to the 10X/20X power switching arrangement. This requirement would be met by using a bolted-on plate about 2 feet long across the top and the bottom of the optical supporting structure and centered on the optical axis of the machine.

3. <u>The Zoom System</u>

The zoom system would be mechanically compensated. [redacted] STAT believed the optical mechanical system must hold its position within 0.002 inch tolerance and he felt this could be accomplished with a face cam and without any electronic compensation. This tolerance is well within the 0.0005 inch tolerance achievable today for a cam surface position. In addition, the design would include the use of hardened cams, drive gears, and worm gears.

A zooming speed for the system was suggested as 10 seconds for a full cycle. At this rate of speed, the zoom system would cycle 360 times per hour, and with 5,000 hours as a test criteria, 1,800,000 cycles of operation would be expected.

4. Anamorph

The main optical anamorph requires a prismatic system to achieve the necessary 1,000 line pairs per millimeter resolution.

5. Image Rotator

[redacted] plans to use Pechon prisms to achieve image rotation. STAT
Each pair of prisms will have a trim wedge for centering on the optical path. Trim wedges and prisms would rotate together.

6. Optical Switching

Optical switching would be manually performed at the eye pieces with rotating prism blocks. Each of these rotating blocks would have terminal stops in order to obtain two positions for each prism. The manual selector would include an indexing arrangement for selecting one of the four possible positions. The selector would also initiate appropriate computer and control switching. A relatively long light path is involved in this rotating prism block method, but only 6 inches of space is needed behind the eye piece mountings, since the light path can be folded. (We should bring this method of optical switching to the attention of the successful vendor for our design contract.)

7. Condenser System

The illumination between the last element of the condenser and the film plane must be fully incoherent. [redacted] proposes to include a STAT
diffusing element in the condenser to insure this condition. This element can be an over-polished ground glass giving approximately 10 to 20 per cent of the transmitted light by diffusion. (I felt that [redacted] was a bit STAT
uncertain whether the lamp filament would properly "spread" the illumination and hence his idea to use a small diffusing element in the light system to prevent development of any hotspots at the film plane.)

A zoom lens system would be used on the condenser. Light coverage would be based on the requirement of the 10X to 100X system and therefore the minimum image size would be 0.075 inches in diameter. This is twice the diameter required for the 200X system. Note that the brightness of the light patch on the film would be the same at all magnifications. Therefore the amount of light energy falling on the film at the 200 power setting would be 4 times that theoretically required simply because the area of film illuminated will be correct for the 100 power system.

8. Illumination Lamp

[redacted] had originally requested that an approximately 2 millimeter STAT diameter pupil size be used for the eyepieces for light coverage. [redacted] STAT was willing to guarantee only a 1 millimeter diameter pupil size, but would try for 2 although he did not think it was practical to attain it. The required brightness of the illumination at the film plane precipitated some discussion. It appears that the sensitivity of the eye, i.e., $\frac{dB}{B}$ becomes constant at a light level just over 3 footlamberts. The maximum sensitivity of the eye to light changes occurs at approximately 4 to 5 footlamberts. This level of light would be required in order to best observe a density change of 0.1 in a 0.0 to 3.0 density film. Hence a clear necessity of having some 5 footlamberts of illumination available to the eye.

The lamp suggested was a quartz (iodine) type burned at 75 per cent of its maximum filament voltage. The lamp would be an ASA rated FBV-250 watt with a maximum voltage of 30 volts. It would burn for approximately 300 hrs at the reduced voltage in comparison with a 6-hour full voltage life. The filament area is 0.14 inch by 0.16 inch and the lamp would operate with about 180 watts input. The color temperature would be raised to 3500 degrees K with color filters which absorb about

10 per cent of the transmitted light. The lamp would be equipped with a reflector to redirect energy back to the filament for heating, and also to create a filament image so that reflected filament convolutions would supplement the convolutions of the lamp as seen directly by the optical system. [redacted] estimated that about 20 per cent of the light available at the lamp would reach the eye pieces. STAT

9. General Views and Information

[redacted] voiced the opinion that the detailed design drawings of the optical system should be tailored to fit the optical hardware fabricator who would do the job. I pointed out that we were obligated to develope drawings from which various optical vendors might bid and produce. [redacted] felt ~~that~~ this was unrealistic and that a considerable amount of liaison would be necessary in order to accomplish the job. He estimated that about 6 months would be needed to convert drawings from an American format to a European format or vice versa. He suggested that if we planned to procure the optics in the U.S. we should have the design made in the U S. and similarly, if we planned to procure optics from Europe, to have the design made there. [redacted] freely expressed his views concerning the relative technical abilities for design and fabrication of numerous optical firms throughout the world. When talking about French designers, he definitely commented that one could expect to have an "excellent design job done in France". He used this word "excellent" only with regard to France, and was less appreciate of optical work elsewhere. STAT STAT STAT

[redacted] pointed out that U.S. drawings use third angle projection and British drawings use first angle projection. To accommodate interchangeability, some 700 to 800 drawings would require conversion, and STAT for this work alone the [redacted] people estimated a maximum of 3,000 hours would be required. STAT

[redacted] was adament in his view that 6 months work might ensue in completing the design before appropriate interfaces could be provided [redacted] tentatively agreed that it would be possible to cut the 11 month schedule to 10 months by including overtime for the detailed design drafting phase of the work. But they estimated that this would add approximately 25% to the total cost of the job. STAT STAT

I was very pleased with [redacted] frankness and technical presentation in answering my questions. There were relatively few inconsistancies and I felt that [redacted] was a fairly competent optical engineer. On many occasions his answers were so frank that the [redacted] people felt uncomfortable but it was all done in a friendly way and no problems arose in the association. STAT STAT STAT

10. <u>Program Management</u>

Discussion concerning the management of the program was definitely unsatisfactory to me. A Project Manager was proposed who would manage the Optical Stereo Comparator Project and who would be responsible for all aspects of the problem including reporting on job progress.

Partial dialogue on this subject is as follows:

[redacted] Question: "Just exactly what would you answer to the customer, in this case [redacted] in the job report?" STAT STAT

Answer: "We would provide the hours or dollars expended on the job."

[redacted] Question: "What else would you provide?" STAT

Answer: "We would project for the next two or three weeks work what might be accomplished."

[redacted] Question: "Would you provide at the time of the report a cost to completion?" STAT

Answer: "No, we would only look ahead the 2 or 3 weeks."

[redacted] Question: "What sort of charting would you provide for the progress of the job?" STAT

Answer: "We would make bar charts for the various primary design and drafting phases."

[redacted] Question: "The usual bar charting does not show an interrelation between the various elements of the work; how would you propose to do this?" STAT

Answer: "Well, we could do it any way that you wanted."

[redacted] Question: "How do you usually do it?" STAT

Answer: "Well, we don't really usually do this that way."

[redacted] Question: "Have you ever used a PERT type presentation?" STAT

Answer: "Oh, yes, we would be verry happy to provide some sort of PERT type reporting."

[redacted] Question: "When you evaluate the status of a job at a given time, if you are merely looking at the hours and dollars expended, this is history; but what about the actual accomplishment for the job, in other words, the per cent to completion. How would you record that?" STAT

Answer: "Well, we would have a meeting once a week and we could make a progress report."

[redacted] Question: "It appears that this job might be sufficiently complex and have a sufficiently tight schedule so that it would be necessary to have a Project Administrator as well as a STAT

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project engineer. What is your thought in this regard?"

Answer: "Yes, I think you're right, we probably would need to have a project administrator."

FACILITIES

[redacted] employ about 75 persons. STAT

A personal visit through their Production Control office showed nothing that would help any engineering control. The fabrication shop consisted of 8 very small lathes having about 24 inch beds and 18 inch swing; 6 small milling machines; one small surface grinder with an approx. 8 inch wheel and a 10 X 24 inch table; 4 pairs of gauged drill presses; two small punch presses; and a production punch press that was then making parts of approx. 1/4 x 1/2 inch dimensions. In addition to this equipment, there was a full complement of model shop size sheet-metal fabricating equipment, a brake, shears, small punches, etc.

There were 5 people working in the shop during my visit. None of the lathes were operating, but the punch presses and sheet metal equipment were in operation. Small parts for some production operation of the Company were being turned out. No model shop type work was in progress. The combined drafting and engineering areas appeared to have about 30 people, about 1/3 of whom were electronic people. This area was full and all drafting tables in the surrounding offices were in use.

15 June 1967

JOB 302

Optical System Bidders List
~~Image Analysis System Bidders List~~

Two copies Optical System Specification OS-2-302-15/18 and Letter
~~Two copies Image Analysis System Specification C-3-302-25 and Letter~~

Optical System Vendor Evaluation

Optical Survey Reports

STAT

[redacted] STAT

SUMMARY OF VISIT

My visit to [redacted] STAT occurred on May 24 and 25, 1967, with initial contact through [redacted] Technical Sales Manager. [redacted] was, STAT by academic training, an optical engineer or physicist but apparently had not practiced as such recently and was not technically up in this field. Hence his position as Sales Manager. [redacted] admitted that he, STAT not an engineer, had made the proposal, and that it had been taken largely from past proposals after some consultation with [redacted] STAT [redacted] of the company. [redacted] could not understand why STAT the proposal itself was not acceptable as a sufficiently informative document, nor why I wished to discuss the details of the proposal with a technically oriented person.

(I had read their proposal and found it singularly uninformative. It was adequately bulky but did not cover in any specific detail the elements of our system. It talked generalities and mentioned possible problems in many areas. The proper key words were used which would enable one to deduce more or less what the system might look like; but it certainly was not a definitive document upon which to base a technical evaluation.)

I explained to [redacted] that I was not trying to test STAT [redacted] credentials as an optical designer, but that I wanted to STAT discuss the optical system in considerable technical detail in order to understand exactly what [redacted] proposed. My request to STAT speak to the optical designer, the optical systems designer and the mechanical design and systems engineer precipitated much confusion.

It developed that these people do not exist and there was no one who was knowledgeable of our system and who could make an intelligent discussion. [redacted] acquaintance with the project was minimal and STAT relatively transitory, and he was not prepared for a discussion. I insisted strongly on further discussion simply because I felt it necessary to validate the adequacy of personnel and overall competence suggested in their proposal. [redacted] was finally introduced to me as STAT the Treasurer of the Company and entered the discussion. He questioned me closely [redacted] its products, capabilities, resources, finances, and STAT its relationship with [redacted] He seemed satisfied with my STAT answers; I suspect he was motivated primarily by curiosity concerning the financial responsibility of [redacted] receive a STAT contract. This would be quite a normal concern for someone who was not acquainted with our Company.

At this time, a tour of the plant began. We spent a considerable time in a new wing which housed only vacant offices and vacant production areas. I inspected their testing facilities in considerable detail, and saw their in-process lenses and optical hardware.

After being in the plant 5 hours, I was finally introduced to [redacted] He is president of the company and was the only technical STAT person in the Company acquainted with our project. Apparently all management and technical decisions are made by [redacted] personally, STAT and this fact might explain [redacted] reluctance to have me take STAT up [redacted] time earlier. STAT

[redacted] had informed me, by this time, that [redacted] STAT was head of their optical design research department, but that he was unacquainted with the project. In addition, [redacted] was STAT chief mechanical engineer, but he, too, was unfamiliar with the proposal. Only [redacted] was acquainted with our project and he acted as the STAT optical systems designer for their proposal.

CONCLUSIONS

[redacted] was very concerned lest his firm get the design STAT
contract but not receive the fabrication follow-on, i.e. the design drawings might be sent to a number of optical fabricating firms who would later make the parts per the drawings and furnish them to our customer. [redacted] did not seem willing to apply its STAT
design talent and time to a project where engineering was the only result. Their engineering time, [redacted] felt, could be much STAT
better applied to work where they could expect eventually to furnish hardware, thus keeping their shop facilities busy. He planned to discuss this point with our customer and pending the results of this discussion, he would decide whether or not he intended to commit his firm to the design effort. He believed that he might withdraw his bid if the customer could not satisfy the conditions referred to above.

To conclude, I believe that [redacted] is capable of doing our STAT
job but I do not feel that he had a great deal of interest in it. He appeared to be sincere and dependable, and if he actually did accept the work he would probably get it finished. I would expect, however, that it might be delayed or/and that [redacted] would have to spend a considerable amount of STAT
effort to keep the job expedited in an attempt to hold it to a schedule. The administrative and planning aspect of their operations appeared to be at a basic minimum and would probably be insufficient in its present form for our project.

OPTICAL SYSTEM REVIEW

1. Objective Lens System

An F1.5 objective lens with a depth of focus of about .0001 of an inch is proposed. The objective lens would be 1 inch in diameter and

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would be located about 1 inch above the film plane, i.e. 1 inch of clearance over the objective cell. No field flatteners would be required and adequate hold-down might be achieved with a cover plate. I questioned the optical problems that such a cover plate might create, but [redacted] felt that a piece of properly fabricated glass would STAT present no problems with resolution. Actually, with the varying width of film used, the cover plate would present a considerable problem and therefore [redacted] view isn't compatable with [redacted] thinking. STAT

The problem of refocusing as the film is traversed through the system met with contradictory views. [redacted] first remarked that for STAT 1,000 lines per mm resolution there would be no necessity for refocusing on aerial reconnaisance film with a density of 0.0 to 3.0; later he stated that refocusing would be required as the film was traversed through different areas of density. (This change of decision on a technical point was typical of the way the conversation proceeded. [redacted] STAT apparently had really given no real thought to our problem and the [redacted] proposal. His off-hand comments were usually not STAT compatable with other information that I had. When probed deeper, he would shift ground and offer a different answer.)

2. Optical Switching

A 2X switching element between the objective lens and the main zoom system was proposed. This arrangement will permit a 10:1 zoom ratio to be used, resulting in an overall zoom magnification of 20:1. [redacted] stated that his design would be based on a Galilean STAT telescope rather than on microscope design. He believed that optical wander during switching would be about 60 micro inches. Keeping completely on axis during the switching operations did not appear feasible to him.

3. Zoom System

[redacted] was very much opposed to optical compensation for STAT the zoom elements and felt that the only satisfactory method was by using a standard cam-type mechanically compensated system. He did not appear familiar with electronic compensation but understood after I explained to him that we had electronic transducers for position call-out and for interrelation between the various optical subassemblies.

A large concern arose about vibration of the optical system due to motor operation and switching units. In attempting to maintain 1/4 of a micron stability in the optical axis, motors and any other moving elements might cause vibration shifts. [redacted] first suggested using Bowden STAT cables with hand operated drives on all the optical members. On explaining to him the computer operation and automatic interrelation between the various optical elements, he accepted the idea of the motors. But he suggested that they operate through long cables with the motors themselves mounted separately to insure that no vibration is transmitted to the optics.

A much longer zoom cell was suggested than the one proposed by other people and shown in our diagram. [redacted] felt that doubling STAT the length of the unit shown would provide an assembly much easier to design, considering the high resolution required. Actually, this does not present any real problem for us. The optical bridge would merely not have a simple shape; it would have to climb up in the air and then turn down again by the addition of mirrors, etc.

4. Corner Mirrors

Strong opposition was made to the use of front surface mirrors for the corner of the optical bridge. [redacted] felt they were too sensitive to STAT angular aberrations. He believed penta prisms would give much better results since they were insensitive to angular effects.

5. Anamorph Lenses

[redacted] emphatically favored cylindrical type anamorph lenses over prismatic designs. The prisms have an inherent distortion which can not be removed, but the fabrication of the cylinders, while critical, can be done in a theoretically perfect manner to give proper distortion-free systems. [redacted] was proposing a different design concept than others that I had heard. Instead of an angular type of anamorph, he proposed using a zoom type of anamorph. His plan to zoom these two lenses would make the length of this assembly approximately twice that of his zoom element length. This represents a relatively long assembly. [redacted] would need to completely change its concepts relative to the shape of the optical bridge. STAT STAT STAT

6. Light Path Diameter

[redacted] stated that in his design the diameter of the light path in general would be 2-1/2 inches, with the optical cells being about 3 inches in diameter. STAT

7. Image Rotation

K prisms, K mirrors, or dove prisms were not considered satisfactory for image rotation. [redacted] believed that Peshon prisms were the only answer. STAT

8. Optical Switching

A set of plug-in prisms was proposed for optical switching. (This is referred to elsewhere as a ladder type.) [redacted] thought that some of the prisms might serve for more than one function in a system, but he had not thought further to develope this idea. He opposed using swiveling mirrors or prisms, i.e. the switching type of optical components, because he believed the light path cannot be maintained constant during this switching. Hence the superior method of plug-in type assemblies. STAT

9. Eye Piece

[redacted] proposed using a special multiple element, STAT wide-angle, modified Erfel design for the eye piece. He had not considered apodizing on the eye piece assembly necessary, but after discussion, he agreed that it might be advantageous. The evaporation process for apodizing could also be done on certain of the intermediate lenses.

Parallel eye piece tubes were strongly opposed by [redacted] STAT They should converge, he felt, by less than the 5 degrees specified in our request for quote. The 50 inch distance as a focal point for the tubes was agreed to. In addition, [redacted] suggested that there STAT should be a skew adjustment on the eye pieces to independently adjust the up and down position of the eye-piece tubes. Many people's eyes, he explained, are not set at the same elevation in their heads and it is necessary for them to tilt their heads when using these optical instruments. This presents a tiring situation and it should be remedied through use of the skew adjustment.

10. Reticle

A diffraction limited reticle normally would show at least one ring visible. [redacted] however, proposes to put in a stop which STAT would remove that ring. He plans to project a thin-hole image, using an apodized lens. The apodizing removes the ring.

Nor will fulfilling the continuous 4-times spot size requirement be difficult, he felt. [redacted] explained that with a diffraction STAT limiting method, the reticle spot would be distorted into an ellipsoid figure after passing through the main optical anamorph and zoom systems. Further, the reticle spot would increase in size as zoom magnification was decreased. In comparison, a non-diffraction limited spot would decrease when zoom magnification was decreased.

I asked [redacted] whether there was a spot size between diffraction limiting and the 4-times spot size which holds constant regardless of whether zoom magnification is decreased or increased. This question evoked some confusion but no clear answer. [redacted] admitted that he would need to think more deeply on the topic. STAT STAT

The reticle spot would have its own size-changing system and would be based on the projection of an image in the air which is picked up by an optical system and relayed into the main optical path of the stereo comparator. [redacted] appeared to favor the reticle size and shape changing system indicated on the [redacted] drawing included with our request for quotation. When I questioned him in some detail as to the practicality of using an iris diaphram in order to get an eliptical spot, he thought it a good idea and believed that it would turn out to be the best system. STAT STAT

11. Image Wander

[redacted] had not resolved the problem of keeping the image from wandering as the various elements of the system are adjusted. After discussing possible methods he stated that it was a mechanical problem and that it presented no difficulty. He favored what he called "moving the lenses inside of a long tube." I asked him how proper alignment would be maintained, to which he replied that proprietary methods were available for doing this. No further information was forthcoming about this particular situation. STAT

12. Light Source

A light source zoomed to match the cones into and out of the film plane was proposed. The light source must be fully incoherent and this would be accomplished by installing a diffuser near the source. In discussing the intensity of the light required for the system, [redacted] STAT believed that disregarding the beamsplitters and the peculiar problem of the 3.0 density film (which he felt was far too black for any intelligent use), about 40 watts of illumination would be required from a gas discharge-type of lamp source. Considering the number of beamsplitters and the high density film requirements, he concluded that about 1-1/2 per cent of the lamp illumination would eventually reach the eye pieces. A 3 kilowatt lamp should prove adequate. As to adjusting the brightness of illumination, he felt that this could be accomplished by moving the lamp away from a screen. Some hurried calculations supported the feasability of this method for the 3.0 density film change situation. In addition, some filters for brightness variation control might be useful but he favored the moving lamp idea.

With regards to cooling the film under the high light levels anticipated, [redacted] had no suggestions to offer Instead, he adopted STAT the attitude that a "user" problem was involved. Running too dark a piece of film would simply involve the risk of burning it up. I attempted to probe his experience in this area but he reiterated that it is primarily a "user" problem and felt that this type of requirement in our proposal was not realistic.

13. <u>General Views and Information</u>

[redacted] strongly believed that the optical path must be kept STAT as long as possible.

From a cost analysis viewpoint, he showed concerns about "design changes" which could influence his cost. He made a substantial issue over this point presumably in support of his view that the contract must be awarded Cost Plus Fixed Fee. While listening to him attempt to explain the concern in this design change area, I concluded that he really did not believe his own explanations but was merely establishing a position.

The job would not be completed in less than 10 months. Neither by overtime or other method could the time be reduced.

[redacted] volunteered the information that he defined this particular job as an aerial reconaissance type optical system as distinct from a microscope type optical system. He concluded that we should not deal with a microscope design person or manufacturer but instead with an aerial reconnaisance design person and manufacturing firm. STAT

The total of 200 drawings was estimated as necessary for the entire design job.

14. Plant Facilities

The plant was large for its purpose and there was considerable amount of vacant area. The machine tool aspect, however, was limited. About 4 medium-size milling machines and only 3 small-to-medium-size metal working lathes were available. By contrast, there were some 30 glass lens grinding and finishing machines, indicating [redacted] [redacted] glass lens making capability as fairly extensive. There is a well equipped optical test facility which includes a large air shock absorber-mounted optical test bench. In general, all the optical phases of the facility were well represented. STAT STAT

15. Costing

Early in our meeting, [redacted] explained in considerable length why [redacted] was unwilling to bid on any basis except Cost Plus Fixed Fee, i.e. they would not consider any fixed-price quotation. During our conversations there were many oblique references to our mutual customer and it is very possible that the terms of our contract are known to [redacted] This may have influenced their STAT STAT STAT

CPFF decision. The reason given for concern about costing was that [redacted] management knew nothing about [redacted] management STAT and there was some feeling that we and our customer might be difficult to work with, or require them to make repetitious drawings, design calculations, etc., which would add unreasonably to their cost. Such requirements would be entirely beyond the control of [redacted] STAT group and he hence felt that it would be unfair to them, actually impossible for them, to quote on a fixed price basis. My final attempts to discuss the philosophy of costing with him could not move him; as closely as I can tell, [redacted] remains absolutely firm in STAT the CPFF decision.

[redacted] STAT

SUMMARY OF VISIT

I visited Optical Instruments on May 18, 1967, and met with [redacted] President of the Corporation; [redacted] STAT Sales Manager; and [redacted], a mechanical engineer. STAT

An optical consultant, [redacted] had been invited to STAT the meeting but did not appear. He was located later at his home and apologized for his absence with the excuse of being too busy to attend.

I discussed the optical system design for the Stereo Comparator with [redacted] As a geometrical optics designer, he appeared fairly STAT competent and experienced, although my questions to him regarding new state-of-the-art zoom optics indicated that he has not kept up-to-date, or perhaps is not interested in the newer sophisticated optical developments.

[redacted] indicated that the optical design would be largely STAT done by himself. He proposed to hire one optical engineer to help with the program, and to use the services of [redacted] especially for the STAT zoom and over-all development. Optical design would be facilitated by using a computing service that has suitable programs.

When I questioned just how available this additional optical engineer might be, there was no ready plan. Such remarks as "We will find the man and hire him if necessary" were the only assurances given me.

[redacted] stated that he did not propose to hire project STAT planners or administrators for this job. But a maximum number of moonlighters would be used elsewhere.

The only mechanical engineer available was [redacted] STAT
and this man seemed reasonably competent. There was, however, only <u>one</u> drafting table available in the entire plant and that was for [redacted] personal use. STAT

Of the 14 people at [redacted] there is STAT
no one who can be considered responsible for production control or administration. The Sales Manager, [redacted] doubles as Company STAT
Accountant, and the girl receptionist-telephone operator keeps the books.

[redacted] repeatedly pressed me to STAT
express an opinion regarding their chance of getting this job or their position in the vendor evaluations. I pointed out that this was a first round only, and that I neither had an opinion to offer nor was I in a position to offer an opinion at this time. They explained that as a small company they could only work where there was a surety of being awarded a contract. Therefore they were not willing to spend efforts on proposals or other work that might not result in awards. Apparently they have evaluated the Stereo Comparator as a project they would not get under any conditions. I tried to dispel this point of view by saying that from my viewpoint this was a purely objective review of a preliminary nature, and not being the decision maker, I was personally interested only in what I saw and heard. I explained that if additional reviews were required, there would be other people representing contracts, finances, etc., who undoubtedly would wish to talk with them.

I presented [redacted] with a list of questions which he STAT
should answer in order for us to more clearly interpret their response letter in the light of our proposal requirements. The information requested merely clarified schedule, deliverable items, and the cost

breakdown for which they had not shown a separation between design and hardware fabrication phases. They understand that there will not be, from their standpoint, any deviation from their proposal.

[redacted] takes the position that they do not want the design work without carrying through with the fabrication effort, and they will only accept the design if, at the same time, they are contractually awarded the fabrication job in addition. STAT

[redacted] explained to me that their present business level is quite good and that if it keeps up at the same rate for the rest of this year they will achieve sales of approximately $200,000.00. This was of interest to me because for our contract [redacted] has bid [redacted] and this would almost double their amount of sales for this year. STAT STAT STAT

CONCLUSIONS

At this time, without reviewing the additional requested information on scheduling and cost breakdown, it appears to me that [redacted] is not in the first line as a vendor. They are leaning heavily on the design capabilities of [redacted] who, as president of the company, will be busy with many other tasks not related to our project. They are additionally depending on [redacted] who appears to be a busy man, even to the point of not keeping this conference appointment made by him. (Perhaps making consulting appointments and not keeping them is habitual routine for [redacted].) [redacted] apparently does not realize the many hours of mechanical design drafting required for our contract. In effect he said "John [redacted] will pull the job through and we don't have to worry about it"; but John didn't seem able to have much ability to help himself since he was already loaded with work. Nor were there specific plans for adding STAT STAT STAT STAT STAT STAT

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additional drafting personnel or equipment. [redacted] did not STAT
mention using an outside drafting service, but I would expect that undertaking the intricacies of opto-mechanical design plus the many interfaces required would be extremely difficult without jobbing the whole effort on a crash basis. Especially if [redacted] is to STAT
meet their 6 months schedule. I would not at this time rule this company out. If, however, we did eventually go to them, we would have to virtually provide their staff and manage the program for them which I believe would be very costly. Nor would there be assurance that they could really perform as required.

OPTICAL SYSTEM REVIEW

1. Illumination

A light level would be maintained that meets the required level for filling the pupil of the eye. Hence, for all magnifications of the system, the apparent brightness of the image at the eye will be constant.

2. Illumination Source

An enclosed, high-pressure, arc lamp with a power rating of 500 watts would be used. A 300 watt lamp was considered inadequate.

Approximately 1 per cent to 5 per cent of emitted light would likely reach the eye pieces. The remainder of light from the source would be absorbed by beam-splitters, glass, and various steps throughout the system.

No zoom condenser need be used. A fixed-diameter circular spot of light would be projected through the film after passing through an iris diaphram. With increased system magnification the spot of light would reduce in diameter, a typical size being 1/32 inch for the field of view at 200X power. (These data were presented off-handedly, but with confidence, and are not conclusions derived from calculations.)

3. Optical Switching

Optical switching of the eye pieces would be accomplished by using 4 separate prismatic plug-in units. These units would not be separate pieces with separate plug-in action but instead a set which will offer 1 of 4 positions. As each position is selected the appropriate prisms will be introduced within the optical system and aligned with the optical paths.

Whether or not the apparent brightness of the image is maintained at a proper level when both eye pieces are switched from stereo to one optical path was not clarified.

4. Anamorph

The anamorph system would be a prismatic type instead of cylindrical. The latter type was thought to present too many aberrations, nor would it give the required resolution.

5. Image Rotation

Image rotation would be accomplished with Peshon prisms. The problem of image wander inherent with this system was recognized, but [redacted] believed that adjustment could be made in the field to STAT
achieve accurate centering.

6. Zoom System

Zooming would be optically compensated.

7. Reticle System

The reticle injection system would include anamorphic compensation to counter balance the effects of the anamorph system in the main optical path. The reticle spot would therefore appear circular at all times.

The possibility of using a diffraction limited reticle was considered, but discussion of this system was confused. Such points as (1) what effect would occur by the image of the reticle, with its own system of anamorphs, coupled to the image of the reticle passing through the main optical path system of anamorphs?, and (2) just what would be the pattern of diffraction?, remains unclear.

8. Optical Bridge

My idea of [redacted] providing the optical bridge structure for the STAT
optical assembly met with approval. [redacted] proposed to make STAT
initial tests on the optical assembly and on our bridge at his plant. Necessary readjustments and tests would be made when the optical structure arrived at [redacted] A third readjustment would take STAT
place when the entire machine was shipped to the customer's site.

No large shipping or realignment problems were foreseen. This additional readjustment work had not been included in the quotation, but [redacted] seemed disposed to include it, on the belief that it STAT
would not amount to a significant additional cost.

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STAT

V. réf.: ENQUIRY FOR
DESIGN OF AN OPTICAL SYSTEM
OS-2-302-15/18

Gentlemen,

We are pleased that you could grant to us a longer time to send you our proposal for the design of the optical system according to the specification OS-2-302-15/18, and we thank you for it.

We examined the design specifications and we are convinced that we may undertake such design in the required conditions.

We understand that the design must extend to the mechanical components directly related to the optics ; it does not include, however, the complete design of the optical bridge properly said. Good!

You will find here-enclosed a technical outline from which we shall start for the definitive design.

We also noticed that we could be entrusted with the manufacture of some parts or of the whole optical system. If required, we could send you a quotation for such manufacturing.

STAT

Our price for the design as specified will be .....

We think that we could be able to undertake the design within time slightly longer than the imparted time. That particular point together with the technical questions that could arise, would have to be discussed, and we hope that we shall meet you about that matter.

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We shall ask for some payments by instalments during the elaboration of the design.

We hope that you can agree with our proposal, and that we shall soon come to a complete agreement.

Thanking you in anticipation for your confidence, we remain, Gentlemen,

Yours truly.

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Réf. OS. 2. 302. 15/18
JOB/ 302

DESIGN OF THE OPTICAL SYSTEM

FOR AN ULTRA-HIGH PRECISION STEREO COMPARATOR

The general arrangement of the drawing E 4123 will be followed up for the definitive design, it being considered that, to obtain a sighting precision of 1/4 micron, the reticle field injection into the observation field has to be kept as close as possible to the film plane in the optical system, and before the various moving controls for adjustment of the image.

However it will remain necessary to keep the following elements before the reticle injection :

1 - Vertical motion of the objective lens to provide for focus on the film plane.

2 - The moving optical elements of the reticle injection collimator, say the zoom 1 to 10 and switching system for magnification 2 ×, and the elements for reticle size, shape and azimuth control.

Concerning paragraph 1) above, we assume that the focussing on the film plane is operated once for all before the evaluation of each stereogram, and that the possible defects in moving the objective lens are not to be considered for the sighting accuracy.

As for the elements of paragraph 2), imperfections in their guiding, that introduce some accidental parallaxes, will be minimized by having such adjusting elements operating in an optical system working in reduction for the reticle itself. Such condition will be thoroughly examined during the design, so as not to imply too strict mechanical tolerances.

When examining the optical arrangement for the observation system, it appears that the main difficulties to be encountered in the design will relate to the following particular points :

1 - Zoom systems with magnification ratio 10 : 1 or 20 : 1. We own various zoom systems we designed and manufactured as taking lenses for cinematography and television, including 10 : 1 ratio. We are consequently led to consider the combination of a zoom system 10 : 1 and a retractable afocal system affording magnification 2 ×, thus giving finally a 20 × range with a step.

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For the reticle injecting collimator and the illuminating system, we may possibly consider to cover the overall ratio through one zoom system 20 : 1, as they do not require so high performances.

2 - The high resolving power the optical system has to be capable of.

3 - The anamorphic systems, which in their expansion range of 1 : 1 to 1 : 2, have not to introduce a distortion larger than 1 %.

4 - The optical switching, which has to afford in the eyepieces the four modes of operation as required.

The optical system we intend to design would incorporate, in each channel, the following elements :

- The objective lens for focussing in the film plane - Focal length 80 mm - Relative aperture F : 1.3 corresponding to the required resolution of 1000 line pairs in the film plane. The film would be located at the focus of the lens ; frontal distance 9 mm.

- The beam-splitter device.

- The Zoom system constituted by an afocal system with a range of 1 × to 10 ×; it will be derived from one patent of ours : two helicoïdal motions of opposite senses being imparted to two elements, say one moving element constituted by two groups of lenses and, inserted between them, a group moving in the opposite direction.

- The afocal switching system with fixed 2 × magnification.

- The afocal system for anamorphic expansion constituted by a zoom system with cylindrical lenses : one fixed group inserted between a group of two lenses moving jointly.

- An afocal system with fixed 1 × magnification constituted by two converging group of lenses having their respective front and rear focus conjugated, acting as relay for the pupil transport.

....

- A field rotation system through an Amici prism.

- The beam-splitters.

- A retractable mirror system affording 3 out of the 4 required modes of operation of the eyepieces.

- An objective lens that constitutes together with the eyepiece a telescope of 10 × magnification.

- Between that objective lens and the eyepiece, a prism-system reversing the right and left images, and a prism system for the adjustment of the inter-pupillary distance.

The optical system of the reticle injecting collimator will be constituted as follows :

- The condenser lens

- The reticle holding the fiducial mark, at the focus of a 80 mm focal length lens.

- A zoom system 1 × to 10 × or 20 × and eventually an afocal system for fixed 2 × reduction.

- An anamorphic system of a similar type as the one of the observation channel.

- An objective lens (focal length 10 mm) giving at its focus an image of the reticle mark reduced in size by 1 : 8 in average.

- An objective lens (focal length 200 mm) transferring the image of the mark to the infinity, to inject it in the observation channel.

The illuminating system will incorporate a zoom system 1 × to 10 × or 20 ×.

[redacted] STAT

[redacted] STAT

Subject: Request for Proposal OS-2-302-15/18

[redacted] STAT

As a result of our telephone conversation of 19 April 1967, we believe that we can now submit a bid on your specifications OS-2-302-15/18.

We cannot quote as outlined on your proposal schedule as the cost of submitting such a proposal would be greater than our proposed profit on this requirement.

We believe you already know our ability and competance as a result of doing the investigation on this original proposal last year. If we should be successful on this proposal we would hire additional personnel to assure ourselves of meeting all of your delivery schedule.

We are in the business of designing and building optical systems, therefore we submit a firm fixed price of [redacted] STAT for the design and fabrication of your complete system and do not wish to submit separate bids for design and then resubmit for the fabrication. We would deliver all ten (10) items as called for on your schedule but reserve the right to change the delivery to a mutually agreed-on revision. We believe that preliminary drawings should be submitted four (4) months ARO, test and inspection - seven (7) months ARO, etc.

We are willing to post a performance bond but request that payment be made as follows:

1. [redacted] upon placing the order. STAT
2. Monthly progress payments to be paid ten (10) days after being submitted.

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We realize that we are probably putting too much emphasis on methods of payment but we have to pay [redacted] per hour for the use of the IBM 7094 computer and it is our estimate that we will have to pay [redacted] computer time the first month after we receive your contract. If we do not pay this charge we could be stopped from using the computer.

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We hope that you will see fit to give us further consideration on this requirement, as we feel very confident that we could do an outstanding job for [redacted] if given the opportunity to do so.

STAT

Sincerely yours,

[redacted]

STAT

WJH:cb

 STAT

[redacted]

[redacted]

13 May 1967

[redacted] STAT

Berkeley 10, California

Attention: [redacted], Contracts Adminstrator STAT

Gentlemen:

Enclosed herewith is our technical proposal and cost proposal for the Detailed Optical Design of an Ultra-High Precision Stereo Comparator. As will be noted, we are well qualified to do this work, but we are a relatively small firm. Due to the scope of this work and its duration, we would require monthly progress payments after the completion of the second month in accordance with the usual 70% schedule under ASPR or equivalent.

Hoping we may be of service to you, I am

Very truly yours,

[redacted] STAT

President

RRW/bh
Enclosure

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[redacted] STAT

PROPOSAL TO DESIGN THE OPTICAL SYSTEM

FOR AN ULTRA-HIGH PRECISION STEREO COMPARATOR

[redacted] proposes herein to provide [redacted] with a complete optical design, optical and opto-mechanical specifications and tolerances, fabrication estimates, and coördination with the design of the rest of the Ultra-High Precision Stereo Comparator. STAT STAT STAT

[redacted] is particularly well qualified to provide the most satisfactory service here by virtue of its experience with the design and fabrication of unusual optical systems of high precision and its lens design facilities and abilities. Our chief designer, [redacted] is fairly unique in the industry and uniquely suited to this development in that he never designs an optical system that he cannot produce himself, and he is able to fabricate systems beyond the capability of most opticians. This factor insures two things which are to our customer's advantage: One, the final optical system designed is realistically tailored to fabrication and is not just ''good on paper but can not be built''; and Two, that the design is not ultraconservative in the other direction preventing it from realizing its full potential within the state of the art. This intimate contact between design, fabrication, and testing always works to advantage STAT STAT

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[redacted]

but is seldom found in the industry today.

[redacted] has been involved from time to time with the development of photogrammetric instrumentation, principally the taking and ''monocular'' comparator systems. We have the good fortune also, of being a few hundred feet away from both [redacted] [redacted] who are well known and respected throughout the world in the field of analytical photogrammetry and data reduction, and [redacted] who has some reputation for its mechanical prowess with photogrammetric instrumentation.

STAT STAT STAT STAT

The function of the optical system to be designed, as we understand it, is to transform two photographs of a common area, which may be taken with different cameras or from different distances and different orientations, into images at the same scale, orientation, and aspect. This requires several basic optical subsystems: One, a means of rotating the two images with respect to each other; Two, a means of changing the magnification of one or both of the images; Three, a means of changing the aspect or apparent angle of view (obliquity); Four, an illumination system compatible with the above and with a means of balancing the brightness of the two images; and Five, such other optics as are required for viewing, photoelectric pickoff, retical illumination, and integration with the mechanical requirements. Figure 1, shows a block diagram of the optical functions of the system.

Mention has been made of the possible necessity of a zoom illuminator system to mate with the zoom viewing system. Our preliminary investigations preparatory to this writing indicate that it may be possible to design the system to use fixed illuminator optics which provides sufficient illumination for the most stringent high power case and is naturally controlled by the pupils of the system to be uniform of the zoom range. This matter will be extensively investigated in the study phase of the proposed design. The specification for the color temperature of the light source to be in excess of 3500°K may require an appropriate arc lamp such as a Hg-Xe or Xe short arc lamp, although some Quartz Halide lamps may approach this level. The apparent color temperature will of course depend on the filters (cold mirrors, etc.) in the optical train.

The basic objective lens, by present concept, would be very closely coupled with the reticle insertion system for stability of the reference point in photogrammetric work. The nature of the [illegible]ll requirements makes the reticle insertion system rather complex. Since its image is to be variable in size and circular and yet is operated on by the zoom and anamorphic optics of the main system, the reticle system must have a zoom and anamorphic optics to compensate for the main system. The reticle will be a bright circle or spot of variable brightness.

The image size, aspect, and orientation optics constitute the most sophistication of the system and may be integrated in various

STAT

ways. The exact order will best be determined after the design study has progressed further.

Image size must be variable over a 20 to 1 range with a zoom system. We reserve the possibility of doing this with a 2X magnifier and a 10X system if a 20:1 zoom proves to be less practical. We favor an ''electrically compensated'' zoom system at this time where the lens positions are controlled by ''electrical cams''. The stringent requirements of this system make an optically compensated zoom seem impractical because of the residual focal shifts. We are currently working on a 50:1 ''electrically compensated'' zoom system for a very special application and some of the results of that work should be beneficial here.

The image aspect must be controlled by a variable anamorphic magnification of up to 2:1 in any azimuth. We will make extensive investigations to find the most suitable form of anamorphic lens for this system, but at the present time a double transfer system as shown in Figure 2 seems most favorable. The system consists of two anamorphic lenses with a $\frac{1}{\sqrt[4]{2}}:\sqrt[4]{2} = 1:\sqrt{2}$ ratio back to back which can be rotated with respect to each other and as a group. In one orientation, we get $\frac{1}{\sqrt[4]{2}}:\sqrt[4]{2} \times \sqrt[4]{2}:\frac{1}{\sqrt[4]{2}} = 1:1$ and when turned 90° we get $\sqrt[4]{2}:\frac{1}{\sqrt[4]{2}} \times \sqrt[4]{2}:\frac{1}{\sqrt[4]{2}} = \sqrt{2}:\frac{1}{\sqrt{2}} = 2:1$. We would like to discuss the acceptability of this with the customer as opposed to a $\sqrt{2}:\frac{1}{\sqrt{2}} \times \sqrt{2}:\frac{1}{\sqrt{2}} \times \sqrt{2}$ pair which could also be used but would suffer from greater aberrations. This would have an affect on the

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[redacted]

400:1 ratio on one axis. The first system described would only go to a 283:1 maximum ratio while the other axis would be 141:1. It appears that this system would have a significant performance advantage and yet achieve the desired result. We have, in the past few years, designed and fabricated several anamorphic lenses. We have computer programs which we developed several years ago for designing such systems. Although our experience with a variable anamorphic system as required here is not extensive or recent, we feel we understand the problems and solutions and that we are well qualified to apply our talents to an optimum solution for the problem at hand.

The image rotation or orientation system will need to be chosen in detail when the rest of the optical system takes shape. It is hoped that the more sensitive and complex systems such as the Peschan prism can be avoided in favor of a reflecting equivalent of the Dove prism, or the like, as shown in [redacted] Optical Schematic. The handling of this subsystem is relatively straightforward from a design standpoint.

The beamsplitters, and mode selection optics are also reasonably straightforward. The major considerations here will be geometrical and coating considerations.

Figure 3 shows the general layout of the program management task chart. The figures indicate approximate manhours from point to point. [redacted] is willing and able to provide the necessary manpower outlined for this project. The project management is somewhat simplified by the fact that we are a small organization and the project engineer, chief optical designer, and chief administrator would be in extremely close and continual contact since they are all one individual, [redacted] He would be supported by a senior optomechanical engineer with whom we are now negotiating employment for our general technical staff, and an optical engineer. [redacted] competence and ability to successfully complete complex optical designs is demonstrated by the work referenced in his resume'. We will be pleased to provide a list of all of our customers, almost all of whom are quite satisfied with our work and continually bring their optical and optomechanical problems to us.

Our optical design computer programs which we use on the various IBM 7000 series computers are, on the average, second to none in the industry. They include automatic optimization of lenses, aspheric surfaces, cylindrical and cone shaped surfaces, torroidal surfaces, MTF computations, automatic focus search, automatic centroid location, spot diagram production (automatic plotting), test data computation for aspheric tools and Foucault tests and Gaviola's Caustic test, and evaluation programs for lenses with tilts and decentrations for tolerance studies.

Although the task is a difficult one, we anticipate no major technical stumbling blocks. The schedule will be difficult but not impossible to meet, mostly in that the Preliminary Drawings might be

[redacted]

STAT

subject to some change after the 3 months point, due to optimization of the lens design after that time. In conclusion, [redacted] STAT [redacted] STAT is particularly well suited to this development because of its ability to devote its unique talents in a very efficient manner to achieving a satisfactory result at a minimal cost.

FIGURE 1
OPTICAL SCHEME

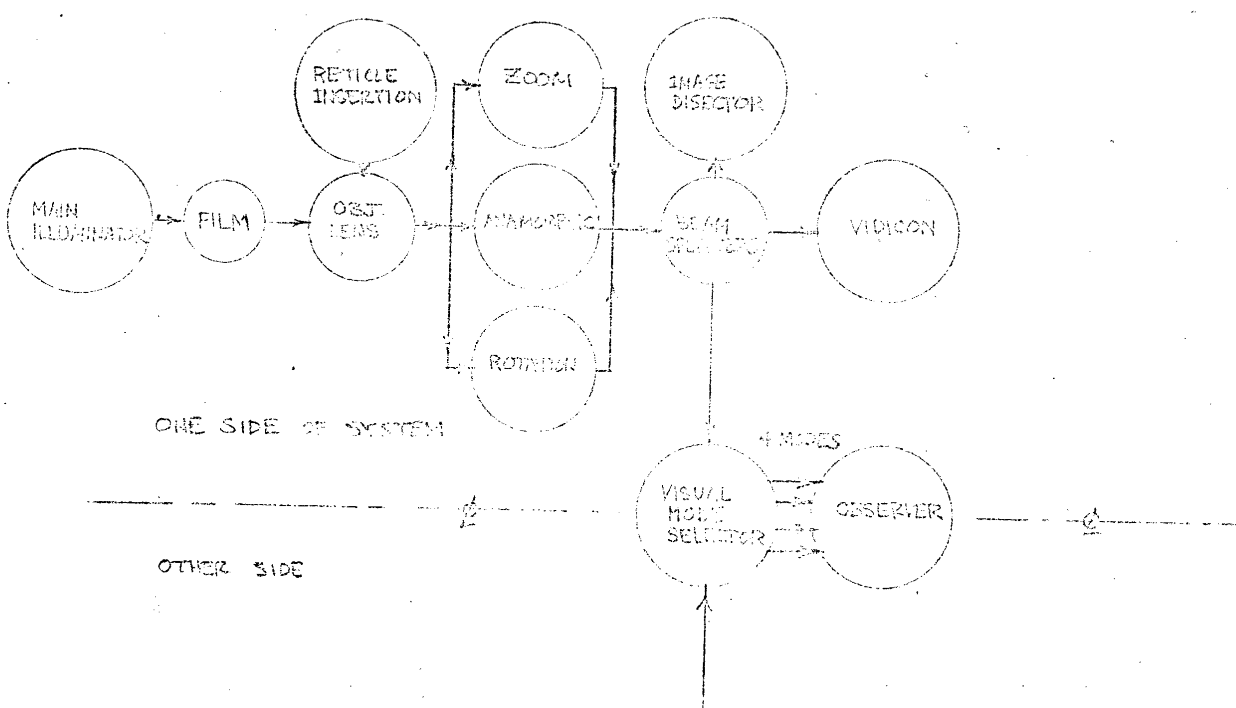


FIGURE 2
ANAMORPHIC
LENSES

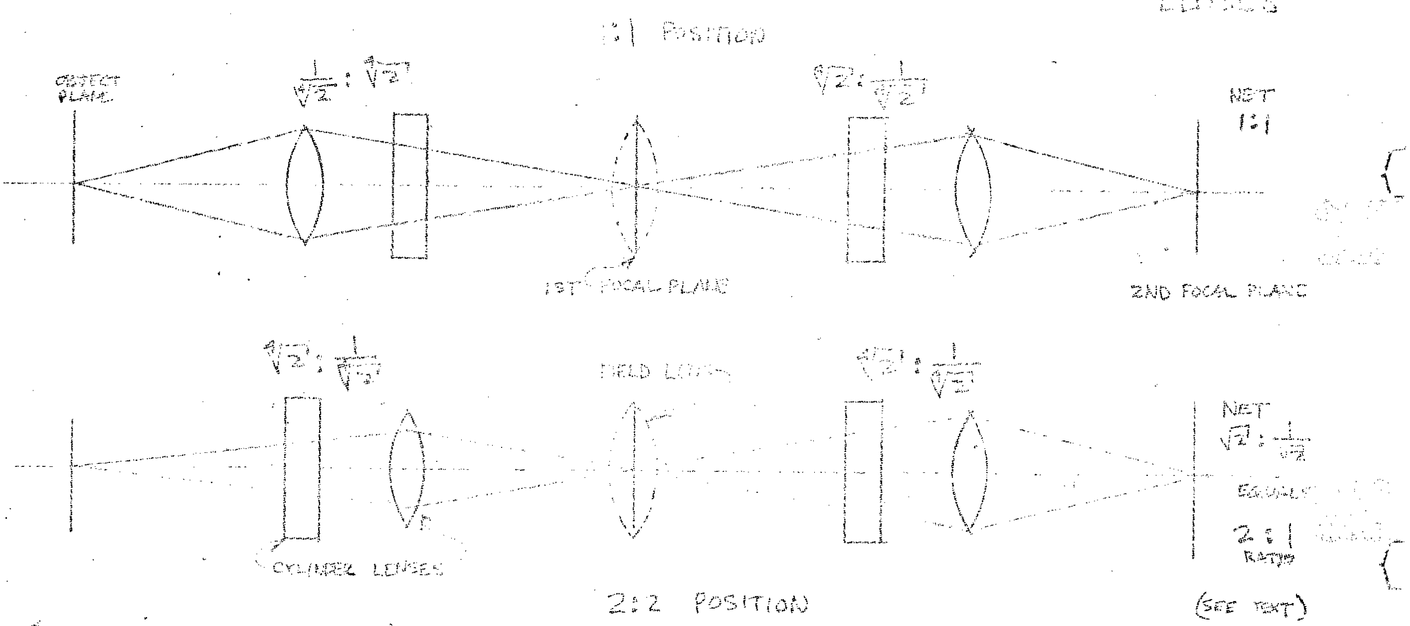
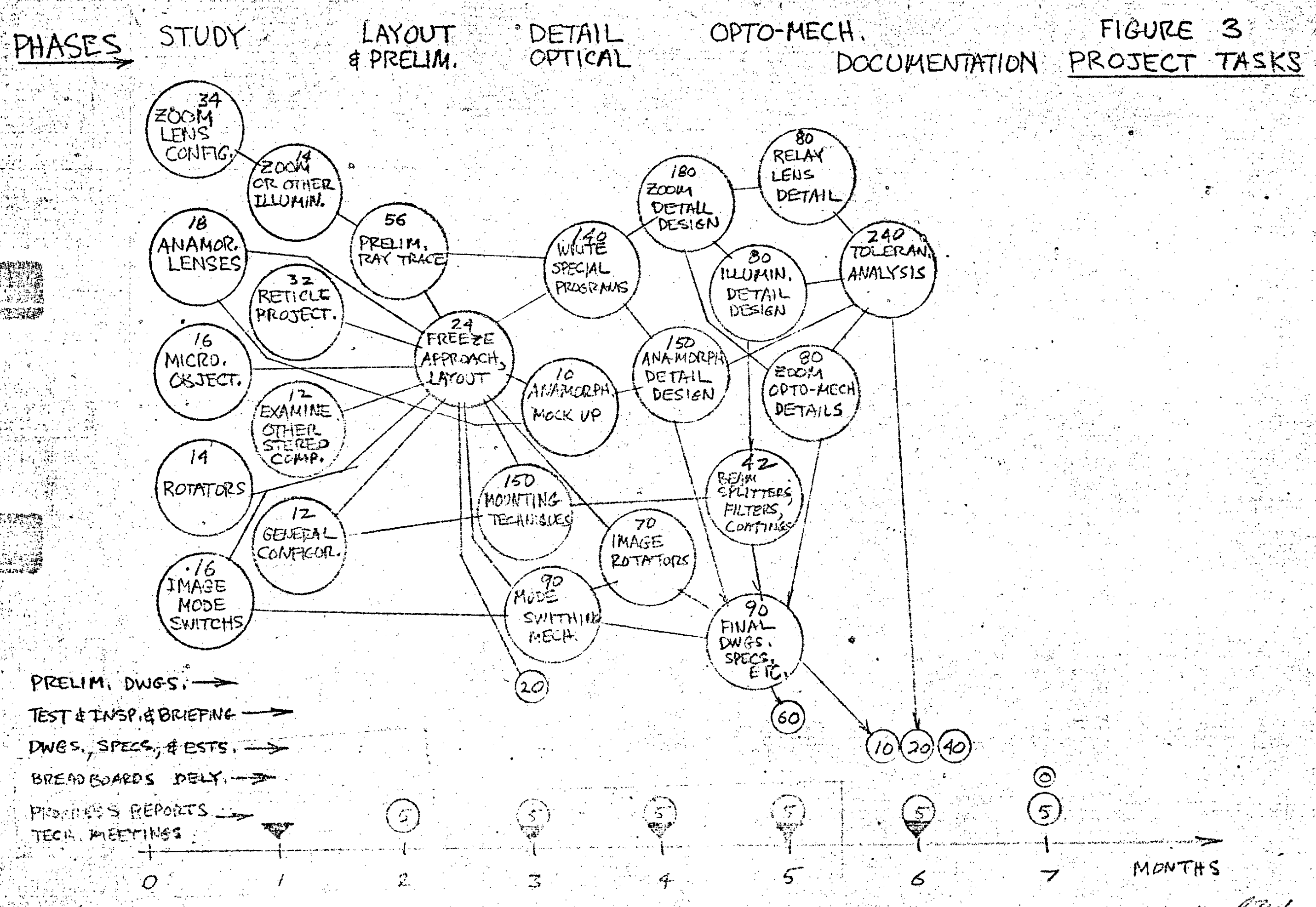


FIGURE 3
PROJECT TASKS



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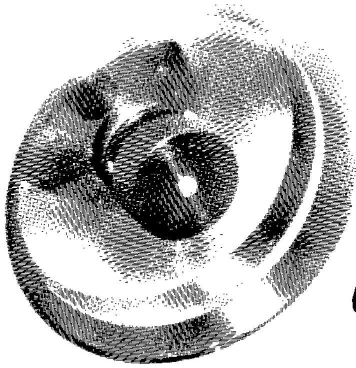
√COMPACT
√VERSATILE
√HIGH RESOLUTION



ULTRA-COMPACT LENS SYSTEM
MODEL 201

STAT

This lens is of long focal length (72") but of very short actual length (6.625"), and it is designed for high resolution photography and observation of objects at great distance. Uses include the observation and photography of: Missiles, astronomical objects, birds, ships, and other remote objects. The optical design is such that near perfect performance is achieved over the entire format of a 35 mm camera.

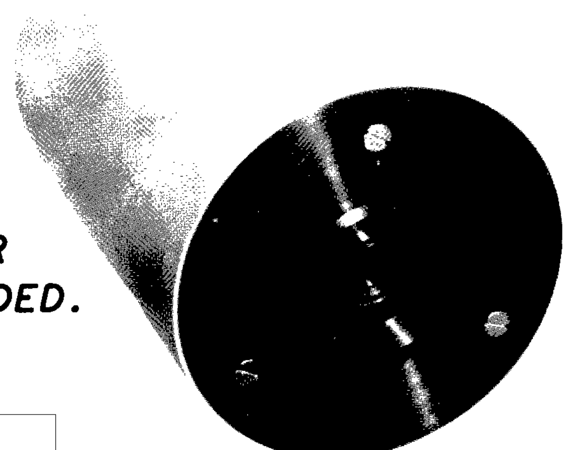
OPTICAL CHARACTERISTICS

Aperture: 4.0 inches
Focal Length: 72 inches (convertible to 24")
Field of View: 1.2° diagonal
Resolution: 1 arcsecond
Focus Range: 100 feet to infinity
Spectral Range: 3,800 to 25,000 Å

MECHANICAL CHARACTERISTICS

Weight: 2.6 pounds
Diameter: 4.75 inches
Length: 6.625 inches
Camera Mounting: Adapters available for most standard 35 mm cameras
Tripod Mount: Flat plate with 1/4" - 20 female hole
Finish: Anodized aluminum

NOTE: UNITS TO OTHER OPTICAL SPECIFICATIONS OR FINISHES, CAN ALSO BE PROVIDED.



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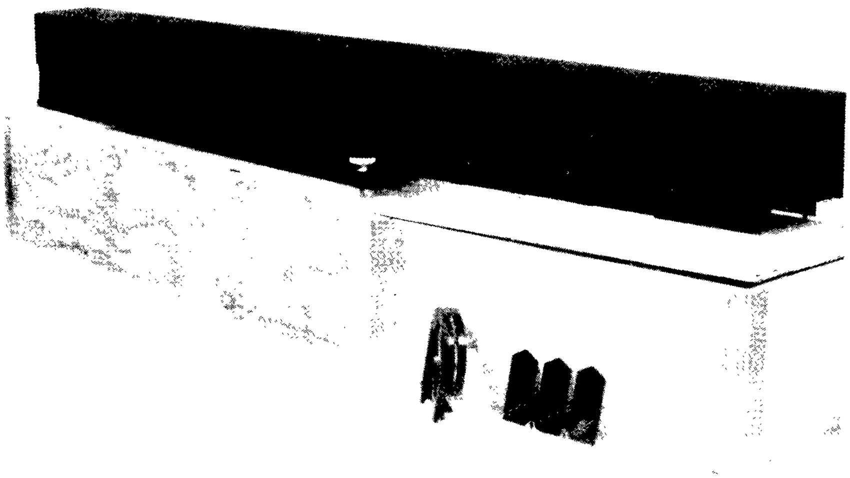

√ACCURATE
√UNIFORM
√ POWERFUL

SOLAR SIMULATOR
MODEL 212

STAT

This Solar Simulator provides a means of testing and calibrating sun sensors and trackers accurately in the laboratory with full sun (in space) intensity with the sun at infinity subtending the proper angle.

OPTICAL CHARACTERISTICS

Light Source:	6500 Watt Xenon short arc lamp which matches sun well from .35 to 3.0 microns with some excess from .7 to 1.5.
Beam:	5.0" Diameter, full sun as viewed from above Earth's atmosphere.
Solar Image:	At infinity, 32 ± 2 arcminutes diameter (20' - 60' optional). Less than 40 arcseconds blur at edge of sun.
Uniformity:	± 6% With ribbon filament lamp; ± 13% over 3" central beam with Xenon lamp. Greater uniformity can be achieved with special lamp, if necessary.

MECHANICAL CHARACTERISTICS

Instrument and mounting table is 9 feet long, weighs 800 pounds. Beam height above floor can be set at time of order, approximately 4 feet. All surfaces dull black.

Requires:	10 KVA of 220V, 3 phase, 60 cycle power also less than 1 KVA 110V, single phase, 60 cycle. Cooling water (ordinary tap and drain will do). Cooling air (ordinary shop air line without condensed water). Exhaust for ozone is recommended.

NOTE: UNITS TO OTHER OPTICAL SPECIFICATIONS OR FINISHES, CAN ALSO BE PROVIDED

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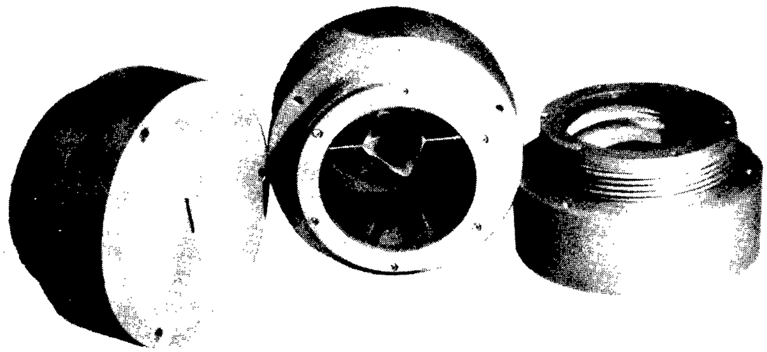

√ RUGGED
√ PRECISE
√ INEXPENSIVE

OPTICAL RETRO-REFLECTOR

Model 213-A, 213-B

These Optical Retro-Reflectors have been designed and constructed to return laser beams, etc. in the direction from which they came and to survive the severe environmental conditions of rocket launch when surface mounted without protective shrouds.

OPTICAL CHARACTERISTICS

Aperture: 3.0 inches
Return Area: 6.9 inch^2 on axis, 3.8 inch^2 at 15° off axis
Spectral Range: 4500 – 20,000 angstroms
Return Beam Pattern: Model 213-A, 2 arcseconds spread
Model 213-B, Uniform spread of ±10 arcseconds to compensate velocity aberation

MECHANICAL CHARACTERISTICS

Weight: Model 213-A or -B, 3.5 pounds; -AL or -BL, 2.5 pounds
Diameter: 5.0 inches outside
Depth Overall: 2.75 inches
Mounting: 1 in. depth of 4.00-8 thread per MIL-S-7742, lock screws in flange
Finish: Irridited aluminum housing
Sealing: Unit can be pressure sealed at installation

SURVIVAL ENVIRONMENT

Vibration: 10 to 2000 cps; 30G peak at 200 cps
Shock: 1500G peak for 0.2 msec
Acoustic Noise: 150 DB, peak at 200 cps
Temperature: Rapid rise to 500°F contact air temperature

NOTE: UNITS TO OTHER OPTICAL SPECIFICATIONS OR FINISHES, CAN ALSO BE PROVIDED.

[redacted] STAT

[redacted] STAT

We appreciated the opportunity to talk with you today concerning the:

OPTICAL SYSTEM FOR AN ULTRA-HIGH PRECISION STEREO COMPARATOR.

As I mentioned, we would be happy to work with you on this project, and, in the event you would like to have us work with you, you would probably want to handle it on a phase-to-phase basis, with different allocations for each phase. Of course, these phases would have to be described in such a way that none of them require possible completion of the project. The reason for this is that we work on a time and material basis, and simply sell time, plus material and expenses.

As I also mentioned, this would simply mean that we would practically become part of your organization, in that we would assign all patent rights. Also, if at any time you might wish to stop the project, all drawings, specifications, etc. relative to the project would be yours - - which, of course, they are, in any event.

NOTE

It would be my guess that the optical design would cost [redacted] and would take six to eight months STAT to complete.

We are enclosing our Brochure and Policy Sheet for your further information.

Glad to talk to you and we hope to hear from you further.

Sincerely,

[redacted] STAT

[redacted] STAT

POLICY SHEET

1967

Our policy, for all of our clients, is to work on a time and material basis only, with charges made for all Designing, Consulting, Engineering, Computing, Drafting, Laboratory, and Machine Shop work requested, as well as travelling expenses, legal expenses, etc.

Our billing is on a weekly basis, and, because of the nature of our work, which is primarily original development, we are unable to give quotations or estimates for completed projects. However, we can, in a general way, advise about costs.

Our rates for the period shown above are as follows:

[redacted] STAT

[redacted] STAT Senior Engineers
Optical Engineers; Optical Designers; Optical Technicians; Computer Operators; Draftsmen; Instrument Makers, etc.

Our charges for Electronic Ray Tracing are based on ten cents per normal ray surface.

We wish to express our gratitude for every opportunity to be of service.

[redacted] STAT

November 1, 1966

STAT

[redacted]

May 5, 1967

[redacted]

STAT

Subject: Management Proposal for Design & Development of an Optical System for an Ultra-High Precision Stereo Comparator [redacted]

STAT

Reference: OS-2-302-15/18, Job 302, April 5, 1967

[redacted]

STAT

We are pleased to submit our proposal for the above referenced subject.

The technical requirements and contractual provisions have been carefully reviewed and we feel confident that the program can be undertaken and completed to your satisfaction.

Thank you for this opportunity to work with your firm.

Yours very truly,

[redacted]

STAT

Manager, Program Development

MCC:jc

Enclosures

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Creative Engineering for Industry

TABLE OF CONTENTS

Introduction and Summary

This Technical Proposal covers the engineering, development, detail design, and preparation of manufacturing drawings of the optical system for an Ultra-High Precision Stereo Comparator.

[redacted] will supply the optical design and mechanical design STAT
for correctly interfacing the optics and necessary electronic inputs and outputs. We will also supply specifications, test requirements and a cost estimate for manufacture.

The range of magnification of 20/1 together with a resolution of 1000 lens/mm. required by the specification, have been studied, and we feel that this cannot be met by the use of only a single objective and a 20/1 zoom lens. We therefore propose a 10/1 zoom lens and two objective lenses to cover the magnification range. We foresee no major problems in the remainder of the design program. By adopting specialized design techniques and correct tolerancing, the design specifications can be met. The mechanical design approach will use modular assemblies to minimized interfacing problems, and simplify final alignment of the overall system.

The Task Description shows the various phases of the design breakdown, and the allocation of design responsibility in each area.

The requested schedule of six months has been carefully reviewed, and due to the complexity of the optical and mechanical requirements, felt to be inadequate. We therefore propose a 10 month schedule for the completion of the project. Six months after the start of the project, sufficient layout and detail design will have been accomplished to cover all aspects, the optical design, physical placement of components and modules to ensure correct interfacing with the [redacted] mechanical and electronic design. The balance STAT
of the schedule will mainly be devoted to producing detail drawings, specification requirements and fabrication estimating.

We regard this project as a highly exacting task. The performance requirements for high resolution and minimum image wander over a 20 to 1 range of magnification can be met only by extremely high quality optical and mechanical design work, and meticulous attention to detail. We believe that the optical and mechanical designers who will carry out the work have the capability and experience to perform the necessary design work at the required levels of quality and precision. Our management control techniques will insure that the job is done with the quality required, and within the proposed firm schedules. We are confident in our prediction that a successful design will be achieved which will meet the requirements.

1.0 DESCRIPTION OF TECHNICAL APPROACH

1.1 Optical Design Concept - The optical requirements of the system may be examined under the following breakdown.

1. Objective and zoom system;
2. Anamorph system;
3. Image rotation;
4. Beam splitters for image dissection and exposure control;
5. Eyepiece prism system for viewing modes;
6. Eyepiece and relay lens design;
7. Reticle system;
8. Illuminating system.

There is a strong inter-relationship between these various sub-systems, and in discussing them there is bound to be some cross-referencing, but the grouping in the above categroies makes for a coherent approach to the whole problem of designing a suitable system.

1.1.1. Objective and Zoom System - The range of magnification required is 20/1, and the first point to be considered is whether this can be achieved in one step, or whether two steps are required.

Zoom lenses are now commercially available with a 16/1 variation (for image orthicon use, Taylor-Hobson) or with a 20/1 variation (for vidicon use, Angenieux), so that there is positive evidence that the 20/1 range of variation, which is required in this project, may be obtained in one step. The deciding factor in making a choice, however, is not the possibility of designing a 20/1 zoom lens, but the capability of the objective lens. At the upper end of the magnification range, a resolution of 1000 lines/millimeters is required. This is an extreme demand and implies that the objective lens is operating under diffraction limited conditions. The depth of field is also defined by diffraction phenomena, and in particular, the limits of the depth of field are set by criteria established by Maréchal.

In order to obtain this resolution in the visible region of the spectrum, the f/number for the objective lens must not be greater than about f/1.5. A choice of f/1.5 for the f/number, however, has two implications:

a) There is no margin of safety for manufacturing imperfections;

b) The exit pupil for the complete viewing system becomes too small. (The diameter of this exit pupil is 250 $\div$ (magnification x f/number). For a microscope at 100 X, the f/number of the objective is normally 2.0, so that the exit pupil has a diameter of 1.25 mm).

If we decrease the f/number, so that the ultimate capability of the objective is increased, and so that the pupil diameter is also increased, then the depth of field is substantially reduced. In the diffraction limited mode the depth of field varies as the square of the f/number. This depth of field has to be utilized in order to overcome the effects of secondary spectrum.

For a system which works only on axis, we can overcome the effects of secondary spectrum by using a reflecting system. In a system which has to cover a more extended field, even at lower apertures (as is required by this project) then the use of a reflecting system becomes more difficult, and contrast is lost because of the annular pupil that is used. We therefore propose to limit our consideration to refracting objectives only.

The secondary spectrum varies directly as the focal length of the objective, and in standard microscope work it is customary to use very short focal length objectives. Such objectives, however, have only to cover a very restricted area, while the present system requires that the objective cover a field of .72 inches diameter under 10 X conditions.

We can gain some relief of the secondary spectrum conditions by noting that the color temperature of the sources may drop to 3500°K. If we take the sensitivity of the human eye in combination with the black body emission curve for 3500°K, we obtain the overall response curve shown in Fig. 1. It will be seen that the overall response is down to approximately 10% at the C and F lines, but that it rises fairly rapidly within these wavelengths. By making an area count we find that approximately 80% of the effective radiant energy is contained between the wavelengths of 520 and 620 millimicrons, with a peak intensity at 565 millimicrons. This has a definite bearing on the amount of secondary spectrum which is permissible. If equal weight were given to all wavelengths in the visible region of the spectrum, then a sufficiently reduced secondary spectrum could only be achieved with an objective lens having a focal length of the order of 8 mm or less. If, however, we take into account only the radiation lying between 520 and 620 millimicrons, and regard the radiation outside these limits as degrading micro-contrast, then it becomes feasible to use an objective, for the upper limits of magnification, of longer focal length.

It does not, however, appear to be feasible to use this same objective, in a zoom system, to cover the .72 inch diameter field required at 10 X magnification.

Considerations of this type, and the feeling for practical optical systems which has been gained by extensive experience with high-performance systems, including zoom systems, leads us to the following concrete proposal for the best way of achieving the desired end results:

1.1.1.1 The magnification will be effected in two stages, from 10 X to 100 X, and from 20 X to 200 X. The transition from one stage to the other will be made by interchanging objectives.

1.1.1.2 For the 20 X to 200 X range, the objective will have a focal length of 1.2 inches and an f/number of 1.2. This objective will probably comprise a 5 element lens plus a field flattener. The clearance between the field flattener with a diameter of .36 inches, and the film plane will be not less than .15 inches, so that an adequate volume of cooling air may be directed at the film.

1.1.1.3 For the 10 X to 100 X magnification, the objective will be a 2.4 inch f/2.4 lens. The resolution obtained at 100 X magnification will be about 700 lines/millimeters. This lens will also probably be a five element objective, with a field flattener .75 inches in diameter, located not less than .25 inches from the film plane.

1.1.1.4 The 10 X to 100 X objective and the 20 X to 200 X objective will be made parfocal, so that the change may be made from one to another without the need for refocusing. The final parfocalizing adjustment will be made optically, since we are considering an adjustment within less than one ten-thousandths of an inch. This optical adjustment will involve a change in the separation between a weak positive and a weak negative lens.

1.1.1.5 Provision will also be made to adjust the objectives so that the lateral displacement of their two image points is less than one-quarter of a micron. The final adjustment to this precision will also be made optically by counter-rotating two weak wedges.

1.1.1.6 The focusing of the objectives will be done by moving them in their carriage in a direction parallel to their optical axis without rotation. It cannot be assumed that tolerances on all components may be held so closely that the movement of an objective along the axis of the metal parts will hold the image position within one-quarter micron. An adjustment will therefore be provided as discussed in the section on mechanical design, to bring the optical and mechanical axis of the objectives into parallelism.

1.1.1.7 A mechanically compensated zoom lens will be used with a 10:1 variation, from 3.16 X to .316 X. This will, in fact, be essentially a variable magnification Gallilean telescope plus an objective lens.

1.1.1.8 The outer elements of the Gallilean telescope will be four inch focal length doublets or doublets plus singlets. The inner moving negative component will have a focal length of .95". This negative component will move, without rotation, through a distance of 2.73 inches. The rear positive component (furthest from the film) will execute a reciprocating movement through approximately .27 inches.

1.1.1.9 The front positive doublet has a diameter of 1.0 inches; the rear positive doublet has a diameter of .325 inches. The negative component will be of three or four element construction, with a diameter of approximately .42 inches.

1.1.1.10 In the course of the zoom motion, it is probable that the optical axis of the system will change the direction in which it points. This will not be a linear function of the zooming action, but by suitable mechanical design approaches and by holding the component tolerances to very tight limits, the linear term in the function expressing the wander of the axis will dominate all other terms and its effects may be eliminated by an angular adjustment of the zoom lens as a whole.

1.1.1.11 The objective will be a 7.60 inch f/24 triplet, covering a field of .72 inches diameter. Special attention will be paid to minimizing secondary spectrum.

The general form of the objectives is shown schematically in Fig. 2a, 2b, and the zoom unit is shown in Fig. 3.

1.1.2 Variable Anamorph System - There are two basic forms of variable anamorph to be considered, the cylindrical and prismatic forms.

Of these two forms, cylindrical form at first sight appears to be very attractive, particularly since there is no axial displacement between ingoing and emerging beams of light. An anamorph of this kind is essentially a cylindrical version of a 2:1 zoom lens. From the conceptual point of view there is no particular difficulty in making the transition from a spherical surface zoom lens to a variable power anamorph. What has to be considered are the practical implications of this approach, particularly in the demands that are placed upon manufacturing tolerances.. These fall into two main categories, the alignment of the cylindrical surfaces, the maintenance of this alignment during zooming, and the establishment of the proper surface figure on the cylindrical elements.

Any misalignment of the generators of the cylindrical surfaces produces a shift of the focus in one meridian by an amount which is proportional to the misalignment. For the standards of performance required by this project, the maximum permissible shift is of the order of one ten-thousandth of an inch at the upper limit of magnification. This presents a very different situation from that encountered in cine work, where a shift of ten times this amount may be tolerated.

The tolerance on surface figure must also be related to the high magnification resolution, and this requires a wavefront distortion of less than one-quarter of a wavelength. This kind of surface figure may be achieved with plane and spherical surfaces, or even with aspheric surfaces, but it is exceedingly difficult to achieve with surfaces which do not have an axis of rotation, such as toroidal or cylindrical surfaces.

We therefore believe that the best approach to the variable power anamorph is to use prisms. In many applications of anamorph systems, the lateral shift of the mean ray, as it goes through the prism system, is not of major importance and a two prism system may be used. In the present application, however, where the anamorph is located within an optical train, the lateral shift should be minimized. We propose, therefore, to use a four-prism system as shown schematically in Fig. 4. There may be a small residual lateral shift, but this will not be significant as far as final results are concerned.

In order to secure this condition, the anamorph unit will be located in accurately collimated space, and the aberrations of relay lenses will be individually corrected by making them of triplet form. (This is in contrast to standard practice where doublets are used, with coma left uncorrected in the individual units, and where only the total system is corrected for coma). It will be necessary to over-aperture, by a slight amount, the relay lenses which follow the anamorph, in order to take care of this lateral shift of the beam of light, but this should not provide any problem since these lenses are working at low apertures and there is no significant growth of higher order aberrations when the apertures are opened up.

The dispersions of the prism materials will be chosen to reduce chromatic effects to an imperceptible level.

The angular spread, in any azimuth, of the parallel beams of light traversing the prism system will be kept small by maintaining the focal length of relay lenses as large as possible. This will minimize the unsymetrical magnification and the curvature of normally straight lines that is found in prismatic anamorphs. Because of the low apertures of the relay lenses, of the order of f/24, we do not anticipate any problems in establishing sufficiently long focal lengths for the relay lenses.

With the prismatic anamorph system, any misalignment or maladjustment of components will result in shape errors only, but not in quality degradation. This situation is more amenable to corrective measures than the corresponding situation with a cylindrical system.

1.1.3 Image Rotation - The image rotation devices will be mounted in the same collimated space as the anamorph unit. There are a number of standard units which may be used to effect the image rotation, such as K-mirrors, M-prisms, and so on. The system which we propose to use in the Schmidt (Pēchan) prism. Our primary reason for using this is that the general shape of the reflecting surfaces, as well as the angles of incidence involved, lead to feasible manufacturing conditions. In contrast with this, a Dove prism presents a severe manufacturing problem to get the standard of performance required by this project.

The most important problem is to reduce the image wander, as the Schmidt prism rotates, to less than the prescribed level. A detailed tolerance analysis of glass and metal parts will be made in order to determine whether the image wander may be held by maintaining tolerances alone. It is quite probable that this will involve extremely tight tolerances, and provision will therefore be made in the design for the mounting of a pair of weak contra-rotating wedges which may be used in order to eliminate image wander with the understanding that they will be omitted in the fabrication stage if parts can be made sufficiently precise. The image rotator is shown schematically in Fig. 5.

1.1.4 Beam Splitter System - There is nothing of particular to note in this system. It is listed separately because our current thinking is that it will constitute a separate module. A neutral density partially reflecting coating will be used on the diagonal of this cube.

1.1.5 Eyepiece Prism System - Optical Switching Module for Eyepieces. The requirement is that the observer be able to view in either direct or reverse stereoscopy, or that he be able to view either photograph with both eyes at the same time.

This reduces to a requirement that either image must be available to either eye at any time, so that a switching system which makes both images available independently to both eyes will meet the requirement.

It is proposed to accomplish this optical switching by means of a beam-splitter assembly and a moveable prism assembly for each eye.

A beam-splitter will be placed in each imaging system at the point where the beams are deviated toward the eyepiece system, and will be arranged so that there are two equal tracks generated for each imaging system. The axis of the two tracks will be arranged so that one track from each side will converge to a mirror or prism assembly for each eyepiece. This reflector assembly will be provided with the necessary rotational and translational motions to bring either image to the focal plane of the eyepiece.

The requirement for change in interpupillary distance will be met by coupling the movement of the eyepiece to the rotation of the reflector assembly, or by providing conventional Greenough prisms for eyepiece adjustment.

The requirement for changing the inclination of the line of sight of one eyepiece will be met by providing a $\pm 1/64$ inch movement of one eyepiece.

There is image rotation available in the system, so that there is no need to have the image appear in any particular rotation in the eyepiece, but it is essential that both eyes see the same image in the same azumuth if both eyes are looking at the same image. This makes it necessary to have the reflector assembly with two reflecting surfaces so that rotation of the reflector will not rotate the image in its own plane, as would be the case with a single reflection. The eyepiece prism system is shown schematically in Fig. 6.

1.1.6 <u>Eyepiece and Relay Lens Design</u> - The feature about the eyepiece design which merits particular attention, is the comparatively long eye clearance required, namely, 20 mm $\pm$2 mm. for a focal length of 25 mm. This is distinctly longer than the eye clearance normally obtained with microscope eyepieces. It does not lend itself, for example, to the use of a Ramsden or a Kellner eyepiece, and we therefore propose to use a two doublet eyepiece, or a two doublet plus singlet type of eyepiece. The exit pupil of the eyepiece is limited to a diameter of 1 mm by the overall system considerations already described, and consequently the only aberrations which will require a special effort for their correction are astigmatism, distortion, lateral color, and spherical aberration of the exit pupil. Pupil wander introduced by the variable anamorph is negligible.

A series of relay lenses will be required to transfer the image from the focal plane of the zoom lens to the focal plane of the eyepiece. The exact form of this series will depend upon image inversion characteristics of the eyepiece prism system discussed in Section 5. No particular problems are expected in this area because of the low aperture required for these lenses.

One point that is worth bringing up is the possibility of increasing the exit pupil diameter for the lower ranges of magnification. It is believed, that, with the illuminating system proposed, the brightness level will be sufficient to fulfill the requirements of this project. However, it is somewhat more comfortable to use a larger exit pupil, since there is not the same tendency for viewing to be affected by imperfections in the lens of the observer's eye. This is an additional feature, and will only be added if it appears in the course of the design program that it can be achieved without serious problems. It will require, for example, that the diameters of the moving negative component, the rear positive component in the zoom, the first objective lens and the relay lenses be increased. The f/number of the eyepiece will also be decreased. What we have in mind is an increase in pupil diameter to 2 mm (from 1 mm) at the lower magnifications. This type of increase in diameter, from 1 mm to 2 mm., does not invalidate any of the statements previously made.

1.1.7 Reticle System - The information provided by the reticle system will be fed into the collimated space between the objective(s) and the zoom lens. We propose to leave to a later date the decision as to whether the beam splitter will be of plane-parallel form, or whether it will be a beam splitting cube. The precautions to be taken in order to obtain reproducible results when objectives are interchanged are discussed elsewhere. The reticle system will, of course, move as a unit with the objective pair, so that alignment will be maintained during focusing.

For an exit pupil of 1 mm. diameter, the size of the Airy disc as seen in the focal plane of the eyepiece is approximately .0012 inches in diameter. For an exit pupil of 2 mm diameter, if we can achieve this along the lines described in the previous section, the corresponding diameter of the Airy disc is approximately .0006 inches. The size of the Airy disc in the focal plane of the eyepiece remains constant in size for all magnifications, but because of the varying degrees of magnification, it corresponds to different diameters in the film plane.

If a pinhole of fixed size were used in the reticle system, without any means of varying its apparent size, then the intervention of the zoom unit between the reticle system and the eyepiece would cause the apparent size of the fiducial dot to change. There would, in fact, be an apparent 10:1 variation in size of a fiducial dot, which should preferably maintain a constant apparent size.

We can eliminate this variation in two possible ways. One is to vary the physical size of the pinhole by making it in the form of an iris diaphragm. The other is to vary the size optically by means of a simple zoom system. The situation is further complicated by the stipulated need to vary the size of spot from the diffraction limited dimensions to four times this dimension.

We propose to combine both approaches. The variation through the 10:1 range will be effected by means of an iris diaphragm. A so-called "dog-leg" type of iris blade will be used to keep the size of the iris opening a linear function of the rotation of the control ring. The 4:1 variation in spot size will be effected by a small optically compensated zoom lens.

The variation in spot shape, so that a circular spot is obtained even with the anamorph in use, will be effected by a small zoom anamorph using cylinders. The conditions which prevail in the reticle system are such as to render this feasible. The orientation of the spot will be effected by rotating the anamorph about the optical axis of the reticle system.

The image produced by the train of optical elements listed above will be formed at the long conjugate focus of a microscope objective operating at a magnification (re reduction) of 20:1. This 20"1 reduction eases the tolerance situation considerably. The image formed by the microscope objective will be located at the focal point of 7.60 inch objective having a clear aperture of 1 inch, so that a beam of light is produced having the same diameter as the maximum beam in the collimated space between the objective and the zoom lens. The 7.60 inch figure was chosen quite arbitrarily, because it is the focal length of the lens immediately following the zoom lens, and because it gives dimensions of the iris diaphragm etc. which are quite practical. It will be subject to change during the course of detailed design.

The requirement that when the reticle image is larger than the diffraction-limited dimensions, it should have a sharp edge cannot be completely satisfied. Diffraction will operate to soften the edges of an image which is nominally four times the diameter of the Airy disc, but the necessary care will be taken in the design shapes to correct aberrations so that diffraction will be the only factor introducing softness of the image edges.

A condenser system will be associated with the reticle system, and our present line of thinking is to use a 30 watt lamp (Sylvania BVB 30 watts, run at about 95 volts to provide a life of about 500 hours).

1.1.8 Illuminating System - The prime requirement placed upon the illuminating system is that it shall provide sufficient brightness that a density difference in the film may be perceived even when a film density of 3.0 (i.e. a film transmittance of .1%) cuts down the level of illumination. Conversely for a clear film, with a density of 0.0, the illumination level of the field must be cut back so that the eye is not saturated.

Extensive work has been reported by Blackwell (J.O.S.A. 53, January, 1963, p. 129-161) on the threshold of detectivity at various brightness levels. From this it emerges that if the brightness level exceeds about 10 ft. lamberts, then dB/B or dD is constant.

The black body brightness of tungsten is given as 42.2 candles per square millimeter at a temperature of 3500°K, and 12.15 candles per square millimeter at 3000°K. It is proposed for this project that we use the lower temperature in order to obtain a longer lamp life, and that the 3500 K color temperature be created by a weak blue filter. For coiled-coil filaments, it is recommended by the General Electric Company that a conservative figure for brightness be used which is 10% of the figure quoted. For conversion purposes 1 candle for brightness be used which is 10% of the figure quoted. For conversion purposes 1 candle per square metre is equal to .2919 foot lamberts. Therefore, on a conservative basis, the brightness of a coiled-coil tungsten filament lamp may be taken as $.1 \times 12.15 \times 10^6 \times .2919$, or 3.55×10^5 foot lamberts. If we utilize an optical system in which we are effectively looking at such a source, with its brightness modulated, for different angles of viewing, by the transparency to be examined, then this would be the maximum image brightness. Even if this level of illumination is attenuated by a transparency with a density of 3, and if the transmission of the system is 20%, then the apparent brightness is still 71 foot lamberts. This will be further reduced, in effectiveness, because of the fact that the exit pupil of the instrument is only 1 mm. in diameter, whereas the normal diameter of the pupil of the eye is 4 mm. The resultant effective brightness, under these conditions, is approximately 4.5 foot lamberts. This is within the region where the density difference of .05 may be perceived.

It will be important that, with the condenser system used, light from every point in the field of view on the transparency fills the entrance pupil of the objective in use. A Köhler type of condenser will therefore be used. However, in order to cover the proper field on the transparency, it will also be necessary to use a zoom condenser: otherwise an undue amount of heat will be thrown on to the transparency.

We propose to use as a light source, a Sylvania High Silica Halogen lamp, Type No. ASA #FBV, with a voltage of 30 v. and 250 watts. The nominal filament area of this lamp is .140 X .160 inches. The filament will be imaged on to an aperture stop, having a metal hole .075 inches in diameter. This aperture stop will be the virtual source which will be picked up by the zoom condenser system. In the course of the design effort, we will seek to obtain data which will permit the use of Type No. ASA. #FBT with 30 volts and 150 watts, and a filament area of .140 X .110 inches. The determining factor will be whether the filament image of the lower wattage lamp will fill the .075 inch aperture stop without a lamp adjustment. Our aim will be to use a lamp which can be readily replaced from stock without the need for adjustments in the illuminating system. These lamps are rated at 6 hours of life at full voltage, with a color temperature of 3400°K. By dropping the voltage to 75% of the rated voltage, the color temperature will drop to 3100°K, but the life will increase to 300 hours.

These lamps have very compact filament structures, and the filament, or rather the aperture stop onto which the filament is imaged, will be imaged on the film plane by the zoom Köhler condenser.

No particular problems are envisioned in the design of this zoom condenser since the quality of imagery is of a lower order of magnitude than that required for the zoom lens in the viewing system. We propose to use a 12:1 zoom lens in the condenser system to give enough overfill to eliminate the need for excessively critical adjustments between the illuminating system and the viewing system.

Cold mirrors, of the type made by L.O.F., O.C.L.I., on by Bausch and Lomb will be used either to bend the light path in the condenser or as normal-incidence filters, in order to remove all infra-red radiation beyond 700 milli-microns for the incident beam of radiant energy. Heat absorbing glass will be used to raise the apparent color temperature. This means that there will be a negligible heat rise in the transparent areas of the film. In areas of black and white film with a finite density there is a conversion of radiant energy into thermal energy because of the black-body absorption by the silver grains. This is unavoidable. An adequate cooling of such film areas by black-body radiation will require an excessive temperature rise of the film over ambient temperature, particularly when the zoom condenser unit is concentrating light for the higher degrees of magnification. Provision will therefore be made to direct a cooling air blast at the film area under examination. In the course of the design, we will also examine the practicality of using an air-blast which is cooled below ambient by thermo-electric effects. (We are familiar with systems in which this has already been successfully utilized.)

A beam splitter which follows the image rotator will take light from the beam for an image dissector tube and for a brightness control system. The part of the light which is directed towards the brightness control system will be brought to a constant size light patch on an R.C.A. photomultiplier tube which has zero fatigue. The output of this cell will be used, by means of an electronic system to be supplied [redacted] to control the movement of STAT
two contra-rotating neutral density discs located near the plane of focus of the filament image. These discs will be formed by the evaporation of Inconel.

These also we have used successfully in previous systems with automatic exposure control for vidicon use. We chose this method of alternating the brightness, in preference to more conventional means, because it gives an extended range of controlled brightness that is not readily achieved with an iris, and, more importantly, it does not upset the pupil conditions which are needed in order to achieve the stipulated resolution goals.

The lamps themselves will be outside the base structure, and light will be relayed in through openings in the base structure to the underside of the film plane.

In view of the large number of air-glass surfaces in the system we propose to use multilayer high efficiency coatings on these surfaces, of the type supplied by O.C.L.I. These will have a maximum transmission between 520 and 620 millimicrons. Detailed overall transmission curves will be worked out in the course of the design.

1.1.9 Design Techniques - No unusual design techniques are called for in this proposal. The techniques which are required, including those involved in zoom lens and anamorph design, may be regarded as standard tools in the equipment of any modern design group.

Electronic computers will be used, in particular G-E Time Sharing, Com-Share (SDS940) Time-Sharing, IBM1130 and IBM7094 (Service Bureau computers.) Standard ray-tracing, 3rd order and 5th order calculations are carried out with programs which we have written.

Spot diagrams as such are not printed out, but they are used as an intermediate step in a good approximation to the diffraction limited response. This technique, which was proposed independently by Cox and by Miyamoto, relies upon the use of the first term in the Taylor-series expansion of the wave-front contour, and can be shown to be equivalent to the spot diagram approach plus an additional exclusion principle to restrict the contributing pupil areas. This method was outlined by Miyamoto in Tokyo in September, 1964, and by Cox in "A System of Optical Design".

One point which merits special attention is the matter of tolerance analysis.

The variations in performance which result from tolerances on components fall into two categories. In the first of these categories perfect rotational symmetry of the system is retained, but there are variations in thicknesses and separations, in refractive indices and dispersions, and to a lesser extent in curve radii and asphericity of nominally spherical surfaces. In the second category are the effects due to decentration and to irregularity in surface figure, in particular to the effects of cylindrical power.

In each category we have to distinguish two separate effects. The first of these is a physical displacement of the image, so-called image wander. The second effect is the degradation in image quality.

The treatment of the first of these categories is straight forward. The effects on the aberrational correction of parameter changes are established by ray-tracing. Those combinations which produce the maximum effects, corresponding to permissible changes of the parameters of the system, for the axis of the system and for points at the zone and at the margin of the field, are used to determine the effect upon frequency responee. At this stage, also, those combinations of thickness and separation changes are investigated but laborious process. (It is customarily followed in high volume production where the proper use of tolerances may have a significant influence on tooling costs and piece-part-production costs). The effects of decentration and surface figure, require an extension of optical theory along the lines developed by Maréchal and by Cox (A System of Optical Design). The types of decentration aberration are primarily coma on axis, and an elliptical (astigmatic) light patch at points in the field. The amount of each aberration which results from decentration of any surface is determined by ray-tracing through weakly decentered surfaces. The effects of any prescribed amount of aberration are determined by introducing suitable terms into the MTF calculation, so that the maximum permissible amount of aberration is determined, in terms of its effects upon resolution. From this analysis we determine the maximum permissible amounts of decentration, and this indicates the tolerances on piece parts as well as the type of the mount design.

The extensive use of electronic computers enables a much more thorough tolerance, analysis to be made than would have been possible in earlier years.

1.2 Mechanical Design Concept - The mounting of optical elements, in order to achieve the full potentialities of a design, is an art which calls for a higher degree of skill and experience than is generally realized. It is in fact, more of an art than a science. Elements must be firmly restrained without being strained, and the mount or cell design must minimize decentration without requiring unduly high tolerances. These remarks hold true for both lenses, prisms and mirrors.

From the optical design discussion, it can be seen that the system can be broken down into four major module assemblies. It is planned to design these modules so that each can be pre-aligned and tested before assembly in the main structure. Each assembly will include the necessary motors, drives, potentiometers and the electronic components, so that after mounting into the main structure it can be plugged into the main wiring harness. The mounting method will be such that alignment into the final system will be simplified as much as possible, and the alignment maintained in the environmental conditions specified.

1.2.1 Objective, Reticle and Zoom Module (left and right hand) - will comprise the two objective lenses, beam splitter, zoom lens and reticle assembly.

Each objective cell will be mounted as a unit or sub-assembly, into a carriage which will be indexed in a repeatable fashion very accurately from one position to the other. The positioning design will use the twin serrated disc technique (poker chip type) to achieve the accuracy required. The two objectives will be parfocalized, and the pointing error corrected with the objectives mounted in their carriage using the optical adjustments provided. A reversible drive will be provided on the carriage for indexing, which will require the additinn of a selector switch at the console table. STAT

The carriage will contain the beam splitter mounted as a sub-assembly, with provision for adjustment, and the reticle assembly. Focussing will be effected by moving this carriage as a module on ground and lapped ways relative to the framework of the complete system, so that image wander due to the focusing action will be held within the stipulated limits.

The reticle sub-assembly will require the following actions to take place within the assembly.

a. Closing down of the iris through a 10/1 range in synchronism with operation of the zoom.

b. Choice of spot size through 4/1 range by means of a zoom unit.

c. Choice of spot shape and orientation through an anamorph unit.

Output shafts with motors and suitable signal generators attached will be provided for each of these operations. The exact form of these generators will be decided upon during the design program in conjunction STAT
Preliminary calculations indicate that by holding close, but practical, tolerances, we should be able to secure the low reticle image wander required, without building any special adjustment into the reticle system. This tolerance situation will be subject to detailed analysis during the course of the design. If it appears that adequate tolerances cannot be held, then provisions for adjustment will be incorporated. An adjustment will be provided to permit tilting to align the axis with the beam splitter and objectives.

The zoom lens in the viewing system requires two units to move in a precisely controlled relationship. The first of these is the inner negative component, which moves through a distance of 2.73 inches, and the second is the rear positive member which moves through a distance of .27 inches. With the zoom lens in the high magnification position, an error of .001 inches in obtaining a repeatable separation between the two moving elements will cause a shift in the focal plane of the object (1.2 inch focal length) of .0001" divided by 110. In the low magnification end of the zoom travel the shift is .010 divided by 11 inches, and in the intermediate range it is .001 divided by 11 inches. For the 2.4 inch objective the shift is four times as great. The depths of field at the low magnification end of the zoom range are quite large because the apertures are of the order of 5/12, in comparison with the high magnification end where the objective apertures are f/1.2 and f/2.4 for the two objectives. On the basis of diffraction theory the depth of field at an objective aperture of f/1.2 is approximately .0001 inches, while at f/12 the diffraction limited depths of field is .01 inches. (These are the total depths of field, not the plus or minus values). It then appears that an error in relative position of .005 inches will not result in a shift of focal plane through more than one half of the diffraction limited depth of field. This amount of shift may be achieved with mechanically controlled movements only, by driving the two lens carriers with one helical and one non-linear cam.

At the present time, however, we do not wish to pre-empt all of the available tolerances for permissible errors in the relevant movements of the zoom elements. For this reason we will also examine the possibilities of an electronic feedback system which will control the movement of the central negative and the rear positive components, and which will be capable of ready alteration to accommodate residual focal plane shifts due to the accumulation of tolerances on component parts.

As far as the mounting of elements in the zoom system is concerned,there are two main directions of approach, rod mountings and sleeve mountings. Sleeve mounting is the construction employed in most 8 mm and 16 mm zoom lenses. Elements are mounted in cells which move under cam control, in the metal sleeves of the lens mount. When greater precision is required, and where image wander is a matter of major concern, the cells containing the elements are placed in saddles which move along accurately ground rods, without any rotation of the elements. The mechanical location of components is more accurate with this type of mounting, in particular, as far as repeatability of positioning is concerned. This is the type of construction which we propose to use, whether the movement of the cells is effected purely by mechanical means or by means of a servo system.

It is probable that, in spite of tight tolerances, there will be a small image shift as the lens is zoomed. Since motion without rotation has been postulated, this image movement may be largely eliminated by tilting the axis of the zoom unit, and provision for this will be made in the design.

The zoom lens module will be mounted to a carriage containing the drive motors and the mating ways, for focusing the objective/reticle assembly. The main carriage will then be mounted to the [redacted] structure, through STAT
a three point suspension system to permit ease of final alignment.

Provision for cooling of the film area under observation will be required as discussed in Paragraph 1.1.8. The design of this system will be included with this module, but will mount to the [redacted] structure independently. STAT

1.2.2 Anamorph & Image Rotator Module (left and right hand) - will comprise the variable anamorph, image rotator, beam splitters for the image dissector tube and exposure control. Each unit will be designed as a sub-assembly which will be mounted to a carriage with provision for adjustments. The carriage will contain the necessary motors and drives required for movement of the various functions. The complete pre-aligned unit will mount into the [redacted] structure with provision for ad- STAT
justment with the optics train, and plug into the main harness.

1.2.3 <u>Eyepiece Module</u> - will comprise the eyepieces, relay lenses and prism switching module. The eyepieces will be designed to meet the requirements of interpupillary adjustment of 50 to 75 millimeters, sight angle of 150, independent and continuous adjustment of one eyepiece through $\pm 1^{\circ}$ vertically and independent focusing. The eyepiece cells will mount to a structure containing the beam splitting prisms and mode switching prism assemblies. It is tentatively proposed that the mode switching be done manually by two control levers on the underside of the eyepiece module. If control is required from the main panel, motor drives can be included, but this is not recommended as manual operation at the eyepieces would be a more natural function, and the added complexity is not justified. The complete module assembly will mount to the center pedestal with adjustments provided for final alignment with the remainder of the optical train.

1.2.4 <u>Illumination System Module (right & left hand)</u> - This assembly will comprise the lamp with cooling fan, zoom condenser, cold mirrors for bending the light path, and heat absorbing glass to raise the color temperature. The system will be designed to mount horizontally under the base structure with mirrors to bend the light path to fit within the physical limits, and to bring the light through the base to the underside of the film plane.

1.2.5 <u>General</u> - The position of the 2-relay lenses will not be finalized until the optical system design is partially complete. These lens assemblies will be included in whichever major module assembly is mot convenient, once their position is established.

The mirror or prism used to bend the light beam between the zoom lens and the anamorph could either be a separate module, with provision for adjust-
ment, mounted in the [redacted] structure, or become part of the anamorph- STAT
image rotation major module. This will be decided during the course of the optical layout.

The design techniques used throughout, will be aimed at producing a system which can be fabricated, pre-assembled and major modules pre-aligned before assembly into the final system. Interfacing problems will then be minimized and final alignment kept comparatively simple, with individual optical component adjustment eliminated in the final alignment procedure.

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1.2.6 Manufacturing Drawings - A complete set of manufacturing drawings will be supplied, including parts lists, schematics, and specification drawings. These will be made on either [redacted] STAT
[redacted] whichever is preferred. STAT

1.2.7 Test and Inspection Data - Sufficient information will be supplied so that the required alignment and certification can be obtained for the fabrication phase.

1.2.8 Breadboards and Mock-ups - It is estimated that the only breadboards or mock-ups required, will be of the beam splitter switching system for which shop time is budgeted.

1.2.9 Technical Direction Meetings - It is estimated that three meetings will be required, and will be tentatively set for 2, 4, and 6 months after the start of the program.

1.2.10 Progress Reports - Progress reports will be submitted monthly, and include the information listed in Paragraph 7 of the Schedule of Deliverable Items.

1.2.11 Briefing Material - This material will be presented as requested.

1.2.12 Fabrication Cost Estimate - A preliminary fabrication cost estimate will be made after a six month period, and a detailed Fixed Price Cost Estimate will be supplied when the final detailed drawings are completed.

1.2.13 Electrical Design - [redacted] will supply the STAT
electrical design, but considerable interface details will require to be resolved. We are therefore budgeting time for an electrical engineer to work on the details of drives, switching and wiring requirements.

2.0 TASK DESCRIPTION

The program will be directed by the Project Manager who will be responsible for the overall design effort and liaison [redacted] STAT

[redacted] Staff Consultant, will have the responsibility for the complete opti- STAT
cal design. Under his direction, [redacted] will be responsible for the STAT
detail design of the zoom lens, both objective lenses and the iris diaphragm. He will also act in a consultant capacity for the reticle zoom and anamorph design. [redacted] personnel will work on all the remaining tasks. STAT
The program will then be broken down into these phases:

Optical System and detail design.
Objective and Zoom Assembly
Anamorph and Image Rotation Assembly
Eyepiece Assembly
Illumination Assembly

[redacted] Staff Engineer, will direct the design of the eyepiece beam splitter system, and supply technical assistance throughout the program. This allocation of design effort will enable us to complete the program within the schedule discussed in the following paragraph. STAT

3.0 SCHEDULE

After thoroughly reviewing the detailed requirements of this program, the six month delivery date requested does not appear feasible. The design effort involved is considerable, both for optical and mechanical. It is estimated that approximately seven hundred drawings will be required.

We propose, therefore, to complete the whole program in eleven months, and the Schedule of Deliverable items will be as follows:

3.1 Preliminary Drawing

System Layout - 2 months
Preliminary Module Layouts - 5 months

3.2 Drawings

Complete details of parts lists - 10-1/2 months

3.3 Test and Inspection Data

10 months

3.4 Detailed Specifications

10 months

3.5 Breadboards and Mock-ups

Eyepiece Beam Splitter - 2 months

3.6 Technical Direction Meeting

After 2½, 4 and 6 months

3.7 Progress Reports

Monthly

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3.8 Briefing Material

10 months

3.9 Fixed Price Cost Estimate

11 months

3.10 Hardware Schedule

11 months

At the end of the six month period, sufficient design and data will be available to have established all the requirements for system. These will include physical sizes of individual optic assemblies, module assemblies, mounting methods, and component drive positions so that all major interfacing problems are resolved.

4.0 RELATED BACKGROUND AND EXPERIENCE

[redacted] has a unique background with over sixteen years of experience, and has developed a high-level capability in designing and building special photographic and optical instruments and devices. Included are audio-visual training aids, special cameras, optical instrumentation and tooling, and audio/video equipment for the television broadcasting industry. Several photographic and optical instrumentation projects are illustrated in the following section, and some are briefly described in the following paragraphs. STAT

TARGET MAP COORDINATE LOCATOR (TMCL)

This device combines several systems to automatically select, retrieve and project with high resolution, 70 mm slides from 2,000 on two removable drums. Slide selection, retrieval, projection, and electrostatic print-out of the image are accomplished in less than 20 seconds. The TMCL is designed to specifically speed the job of retrieving maps and charts from files and to provide working copies. It drastically reduces storage requirements, e.g., sectional maps equivalent to the entire European theater of operations can be stored within the unit. An X-Y coordinate readout is provided, permitting the measurement of distances for several different map scales. Other applications, wherever maps, charts, photographs or other information on slides must be quickly retrieved and studied -- include uses in engineering and drafting, land planning and topographical studies, and in medical use of X-ray films. The electrostatic printer was also specially designed [redacted] STAT

The entire project was designed, developed and manufactured in our facilities to MIL specifications. This work was carried out initially for U. S. Army Engineer Geodesy, Intelligence and Mapping Research and Development Agency, although the U. S. Navy has also procured and is using this equipment.

OPTICAL ALIGNMENT & CALIBRATION FIXTURES

A number of alignment and calibration instruments have been recently designed, developed and manufactured by [redacted] in our STAT facilities for the XM-50 Gunners Periscope and the XM-51 commanders Periscope. These fixtures will be used on a tank production program. This work was undertaken on a sub-contract basis for Chrysler Corporation. Most of these projects are for one-of-a-king devices intended for military applications, although several units of each were produced. All incorporated an auto-collimator, and in one case, which is illustrated, twin auto-collimators were used. A special 5-inch in diameter collimator was required in another illustrated project, which used two reticles, (infinity and 600 meters). The optical systems were completely designed [redacted] STAT

NUMERICAL CONTROL SYSTEM

This will illustrate [redacted] electronic capability which STAT may be utilized in systems design.

Under the direction of [redacted] Project Manager-Electronics, [redacted] STAT [redacted] electronics group recently completed the development of a proto- STAT type of the "Cybermat" numerial control system for [redacted]. STAT [redacted] Cybermat systems will be marketed by [redacted] as part STAT of their numerically controlled tube bending machines. Built with solid state components including integrated circuits, Cybermat commands all machine and part shape movements, features a memory system which accepts data from alternate input media, then produces part shapes without continuous reference to a tape or other data. A tape punch is available to record new or modified programs from the control memory. A typical circuit board is illustrated in the photographs following.

BUDGET STATUS REPORT FOR WEEK ENDING Original Proposal TITLE Precision Comparator STAT

May 5, 1967

STAT

STAT

(FORM S-10.2)

W.O.#	DESCRIPTION	TOTAL FOR WK. HRS.	TOTAL FOR WK. MAT.	TOTAL TO DATE HRS.	TOTAL TO DATE MAT.	BUDGET HRS.	BUDGET MAT.	RATE/ HOUR
5640.0	Optical Design for Ultra-High Precision Comparator							
5640.1	Project Manager							
5640.2	Project Administrator							
5640.3	Staff Engineer							
5640.4	Electrical Engineer							
5640.5	Optical Design & System Layout							
5640.6	Design-Objective -Reticle Module							
5640.7	Drafting							
5640.8	Design - Anamorph-Image Rotator Module							
5640.9	Drafting							
5640.10	Design- Eyepiece Module							
5640.11	Drafting							
5640.12	Design-Illumination System Module							
5640.13	Drafting							
5640.14	Checking							
5640.15	Mock-up Fabrication							
5640.16	Cost Estimate							
5640.R	Reproduction Allowance							
5640.T	Travel Allowance							

W.O. No. 5640

SCHEDULE FOR W. O. NO. 5640 TITLE Optical Design for Ultra-High Precision Comparator

STAT

May 5, 1967

	SCHEDULED						MONTHS											
W.O.#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Month Starting																		
5640.1	100	100	100	100	100	100	100	100	100	100	60							
5640.2	40	40	40	40	40	40	40	40	40	40	40							
5640.3	40	80	80	40	40	40	40	40	40	--	--							
5640.4				20	40	40	20	20	20									
5640.5	-----	160	160	160	160	160	160	160	160	80		(OPTICAL DESIGN)						
5640.6			100	120	120	100	100											
5640.7						160	160	100										
5640.8			100	170	170	170	120	80	40									
5640.9						100	200	160	60									
5640.10		80	160	160	160	20												
5640.11				80	160	80												
5640.12				80	160	160	160	60										
5640.13							80	160	160	40								
5640.14								160	160	160								
5640.15		80																
5640.16										100	120							

W.O. No. 5640

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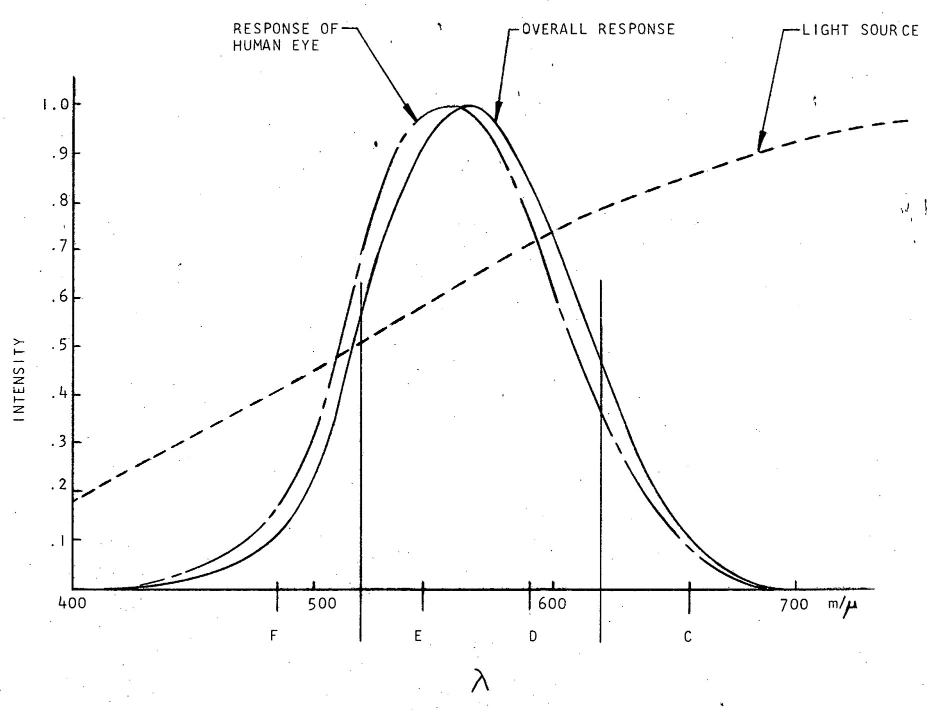


STAT

NAME

OPTICAL RESPONSE CURVES

FIG. 1

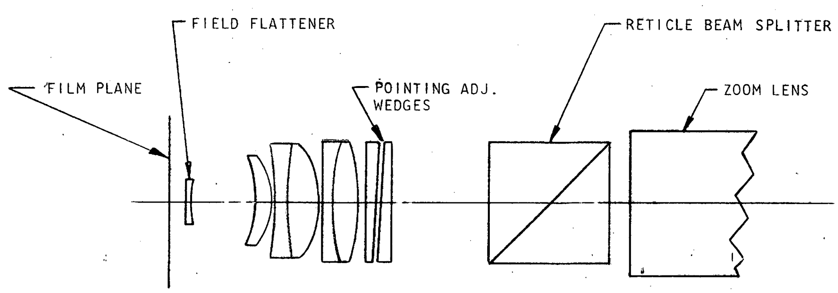


FIG. 2A 20X-200 X OBJECTIVE

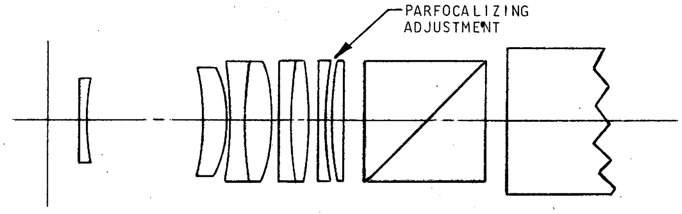
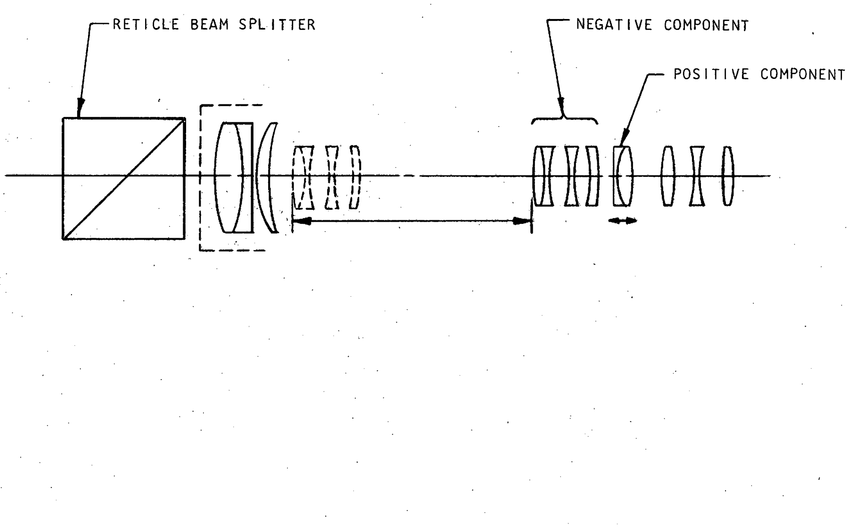


FIG. 2B 10X-100 X OBJECTIVE

STAT

NAME SCHEMATIC LAYOUT OF OBJECTIVE LENSES	FIG. 2

SCALE = 1 TO 1



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NAME SCHEMATIC LAYOUT OF ZOOM LENS

FIG. 3

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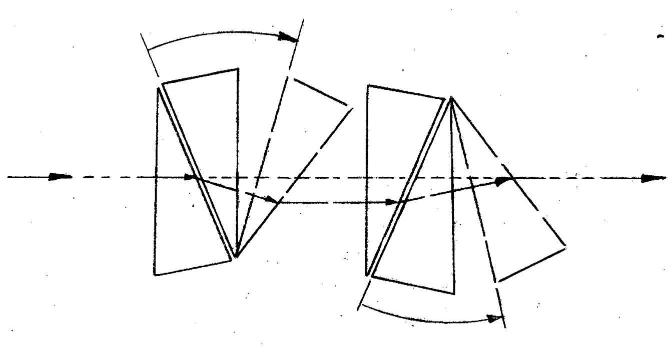
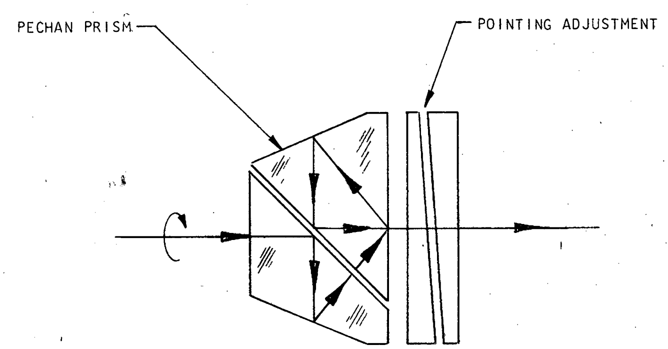


STAT

NAME SCHEMATIC LAYOUT OF 4 ELEMENT VARIABLE ANAMORPH

FIG. 4



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NAME SCHEMATIC LAYOUT OF IMAGE ROTATOR

FIG. 5

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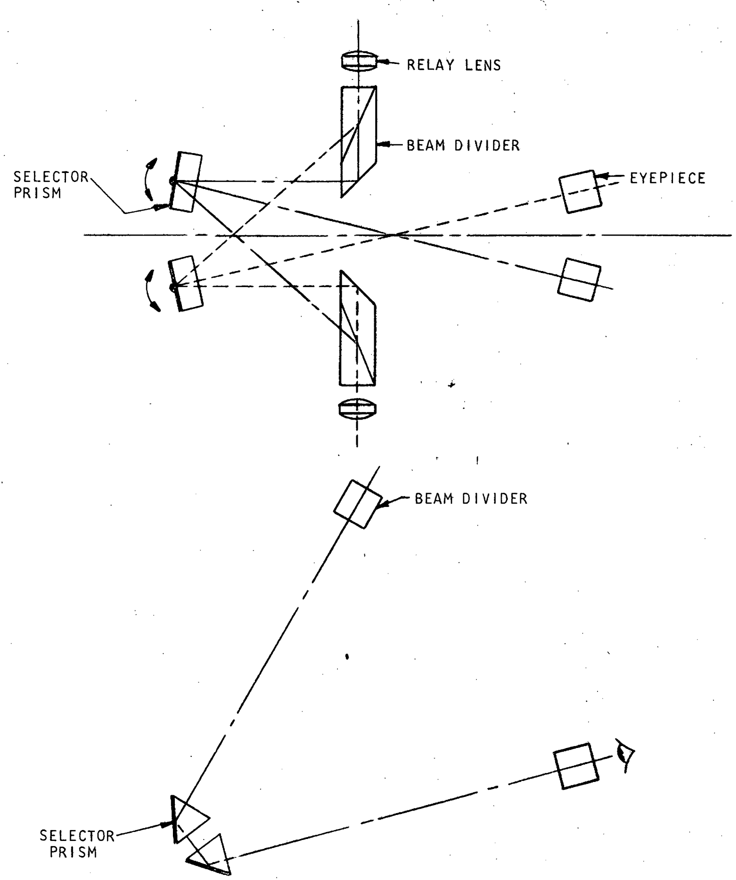

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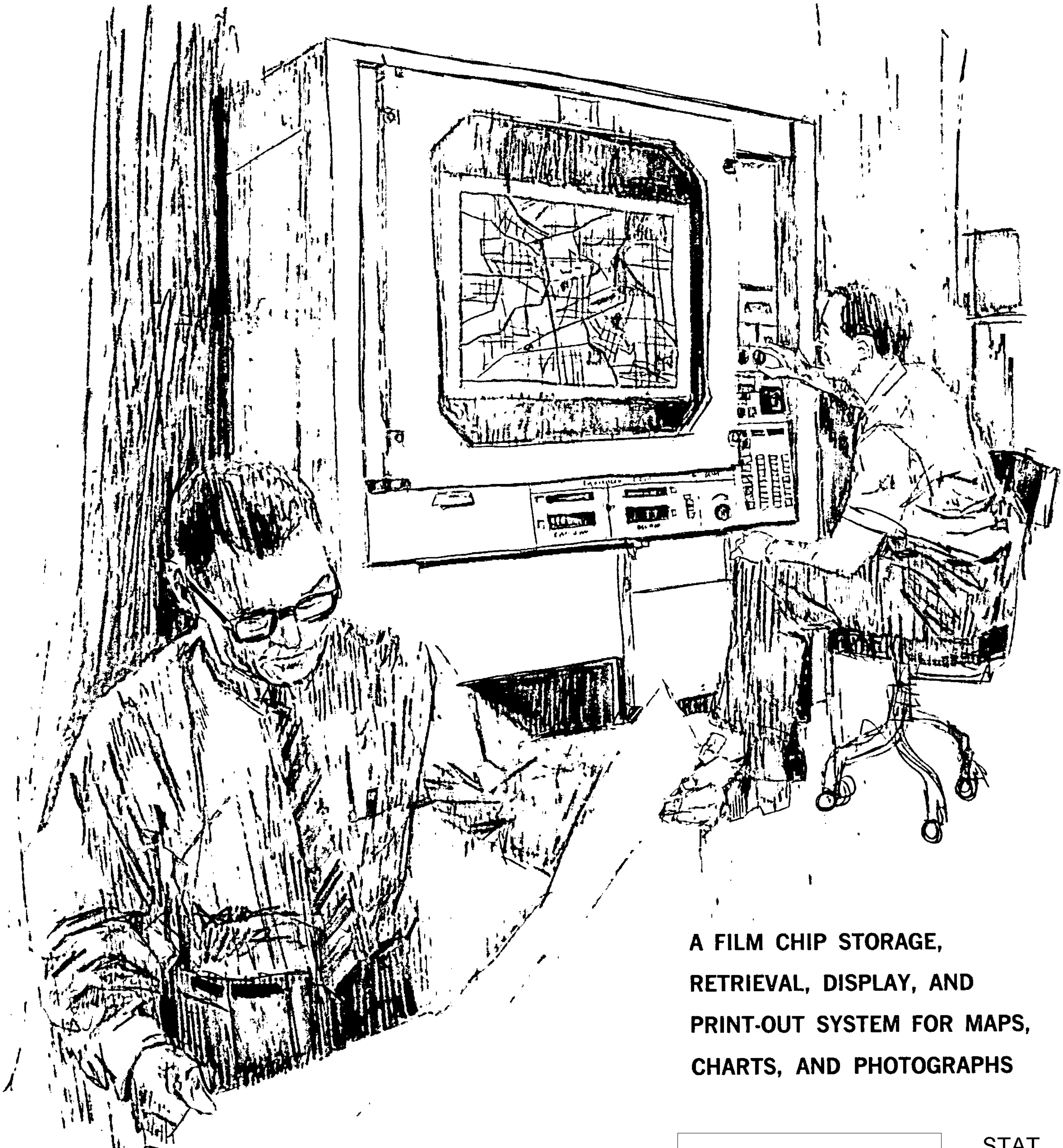
NAME SCHEMATIC LAYOUT OF EYEPIECE SWITCHING

FIG. 6

TMCL TARGET MAP COORDINATE LOCATOR



A FILM CHIP STORAGE, RETRIEVAL, DISPLAY, AND PRINT-OUT SYSTEM FOR MAPS, CHARTS, AND PHOTOGRAPHS

STAT

A FILM CHIP STORAGE, RETRIEVAL, DISPLAY, AND PRINT-OUT SYSTEM FOR MAPS, CHARTS, AND PHOTOGRAPHS

FEATURES

Reduces map, chart, and photo storage requirements; speeds retrieval.

Automatically selects and projects any 70 mm. slide from 2,000 stored on two removable drums.

Additional 1,000-slide drums can be pre-loaded and stored separately.

Has 32-inch display screen with brightness, focus, and image rotation controls.

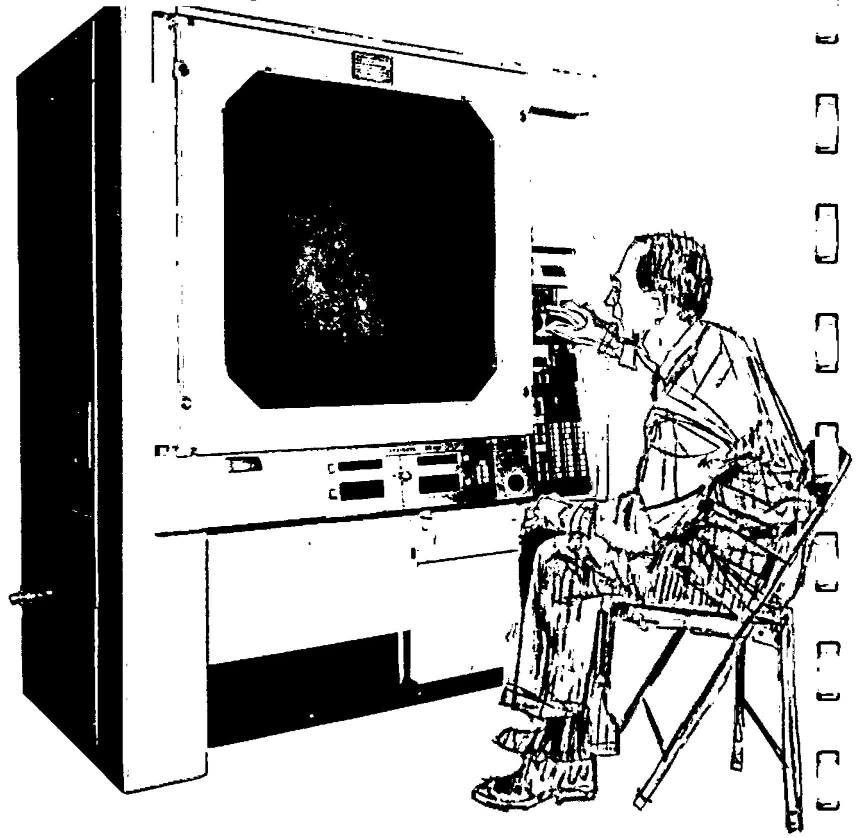
Variable position crosswires pinpoint coordinates, provide six-digit readout.

Plastic overlay screen permits handwritten overlays on projected image.

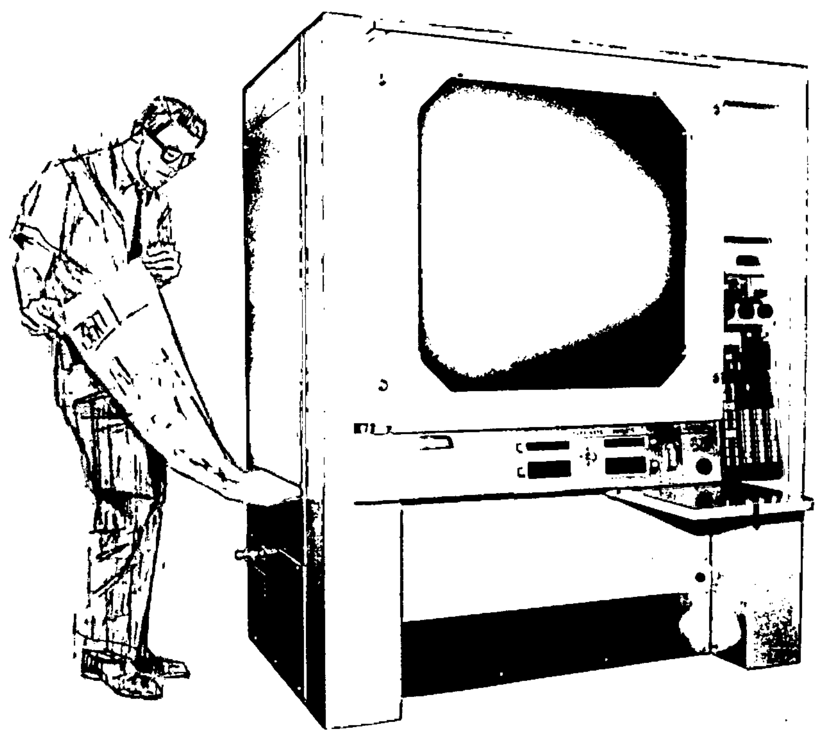
10-second electrostatic printing of image, with or without overlay; produces 22½ x 29-inch copy.

Modular sub-system design permits swift removal and replacement of components for repairs.

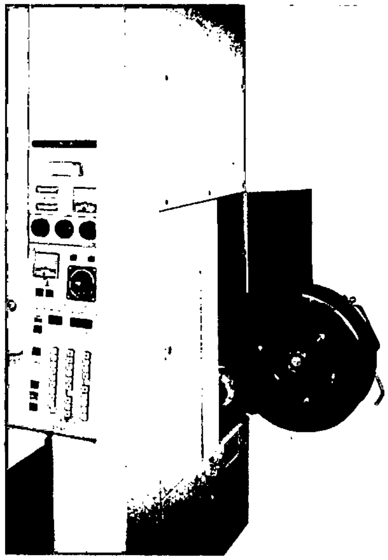
Solid-state circuitry resists shock and temperature extremes.



The operator enters desired slide number on a 30-button keyboard. Slide is rapidly retrieved and displayed on a 32-inch display screen. Brightness, focus and image rotation controls are also readily accessible to the operator.



The TMLC's electrostatic printing system produces a 22½ x 29-inch black-and-white copy of projected image in 10 seconds, with or without overlay information. Copy emerges from left side of the TMCL.



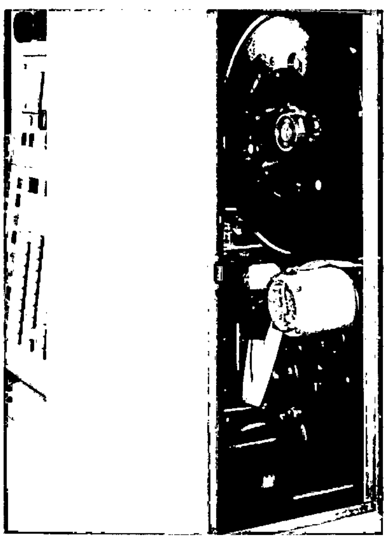
1,000-slide drum can be quickly removed, interchanged with other pre-loaded drums.

In a single unit, the TMCL combines systems for storing, selecting, displaying, and copying maps, charts, photographs and other information stored on 70 mm. slides. At the same time, the TMCL extracts coordinates on projected maps in accordance with universal transverse mercator coordinates.

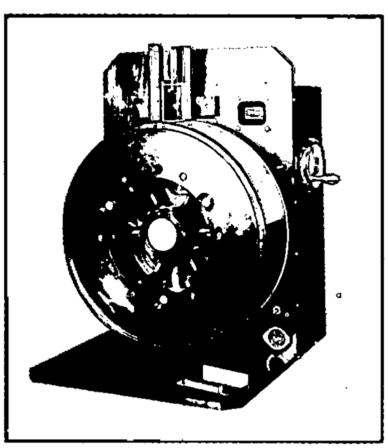
The TMCL is designed specifically to speed the job of retrieving maps and charts from files and providing working copies. It drastically reduces storage requirements; sectional maps equivalent to the entire European theater of operations can be stored within the unit.

Developed for the U. S. Army Engineer Geodesy, Intelligence and Mapping Research and Development Agency, the TMCL has applications wherever maps, charts, and photographs must be quickly retrieved and studied—including uses in engineering and drafting, land planning and topographical studies, and in medical use of X-ray films.

The TMCL is built to withstand a variety of severe environmental conditions, including combat situations. It is housed in a caster-mounted cabinet for stationary use, or can be used in a van for maximum mobility.



Drum in viewing position is ready for selection and projection of slides.



TMCL Drum Loader facilitates precise loading of 70 mm. framed slides in storage drum.

Slide Storage. Steel-framed 70 mm. slides of maps or charts are stored in two 1,000-slide drums within the TMCL. One drum is in viewing position for slide selection. The second drum is on stand-by and can be automatically indexed into viewing position. Other pre-loaded slide drums can be stored separately.

Slide Selection. To select and project a slide, the operator enters the desired slide number on a 30-button keyboard. A high-speed, 200-step-per-second synchronous motor indexes the drum to the desired film position; the map slide is extracted and transferred into the optical system.

Image Display. The selected slide is projected onto a 32-inch square display screen. Brightness and focus of the image are operator-controlled. A rotation control permits squaring up the image on the screen or rotating the slide to any angle up to 100 degrees from its normal storage position.

A light shield built into the cabinet can be extended to screen out overhead lighting. The display screen itself is mounted in a frame which swings out for access to the rear of the screen and to the interior of the cabinet for cleaning the optical system and servicing.

Coordinate System. Two variable position crosswires behind the display screen are visible when a slide is being projected. The operator controls the positioning of the wires separately or together to any intersecting point on the screen.

A six-digit readout for each crosswire may be set by the operator to any number. As the crosswires are moved, the distance in meters is electrically added to or subtracted from the readout.

In this way, the coordinates of any point on a projected map may be determined, or the north-south and east-west distances between two points measured.

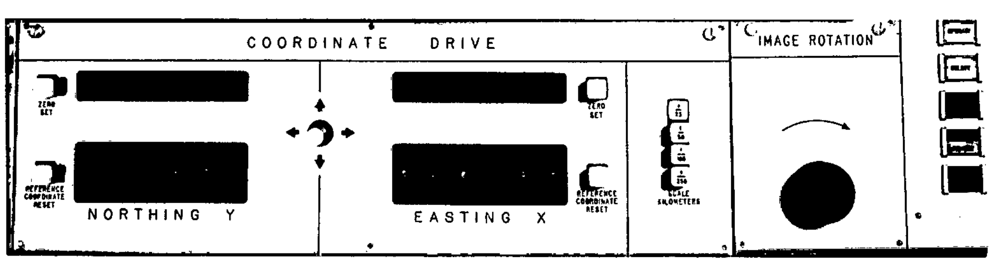
Controls permit the operator to pre-set the coordinate system for the scale of map being projected.

Electrostatic Printing. Built into the TMCL is an electrostatic printer which can be actuated to produce a 22½ x 29-inch black-and-white copy of the slide on display. Controls determine and set exposure time. Additional copies can be made of the same slide simply by repeating the printing cycle. Copies emerge ready to use from the left side of the TMCL.

The electrostatic printer makes it unnecessary to maintain bulky files of full-size maps and charts. Fresh copies can be printed as needed from slides stored in the TMCL.

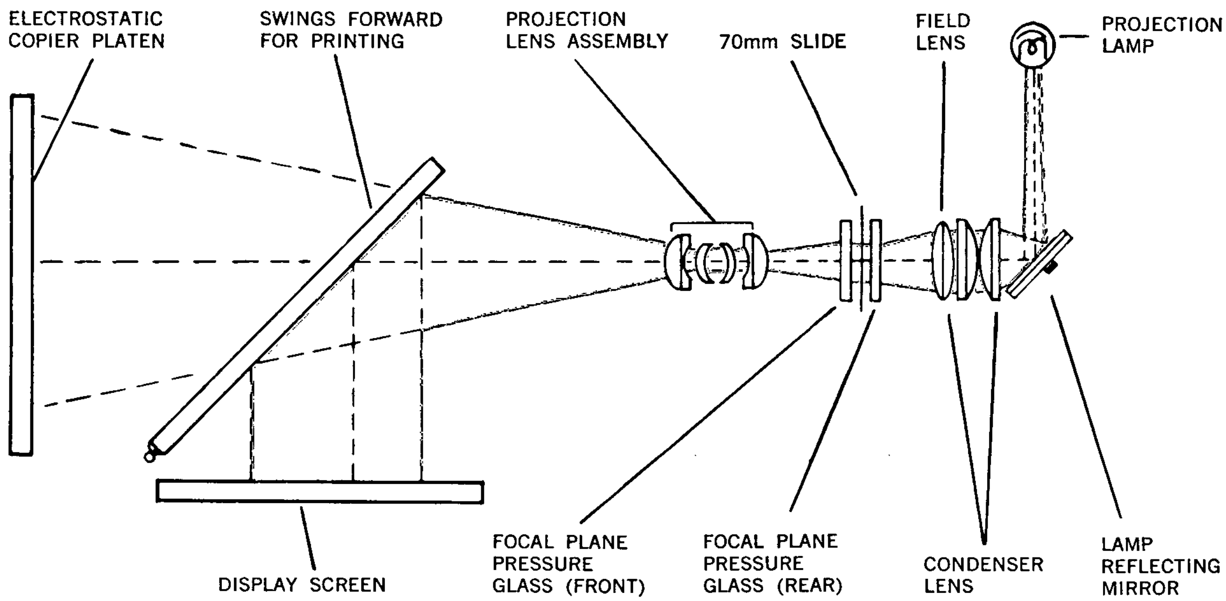
Overlay Screen. A transparent plastic overlay screen is stored within the electrostatic printing system of the TMCL. To make overlays, the operator slides the overlay screen out of the printer, slips it into place over the display screen, and makes whatever overlay notations are needed.

The overlay screen is then re-inserted into the electrostatic printer. When the printer is actuated, the overlay notations are reproduced along with the image of the slide on display.



Joystick control on coordinate drive panel positions image crosswires separately or together. Readouts display coordinate positions, automatically changing as the crosswires are moved.

TARGET MAP COORDINATE LOCATOR PROJECTION SYSTEM SCHEMATIC



SPECIFICATIONS

Dimensions: Width, 59 inches; depth, 35 inches; height, 72 inches.

Slide Capacity: 2 drums of 1,000 slides each.

Slide Dimensions: 70 mm. x 100 mm.

Slide Selection and Extraction: Extraction time—5 seconds maximum. Replacement time—2½ seconds maximum. Time required to replace slide on view with new slide (500 positions away)—9 seconds maximum.

Displayed Image Size: 22½ x 30 inches maximum.

Display Image Rotation: 100 degrees maximum.

Display Screen: Brightness—15 foot-lamberts at any point within 25% maximum overall deviation. Size—32¼ x 32½ inches. Resolution—capable of minimum resolution of 10 lines/mm. on axis and 6.5 lines/mm. at edge of field in projected image.

Coordinate Reading: Total accumulative error of less than 0.155 mm. (0.007 inches) at any map scale. Readout can be set to following map scales: 1/25,000; 1/50,000; 1/100,000; 1/250,000.

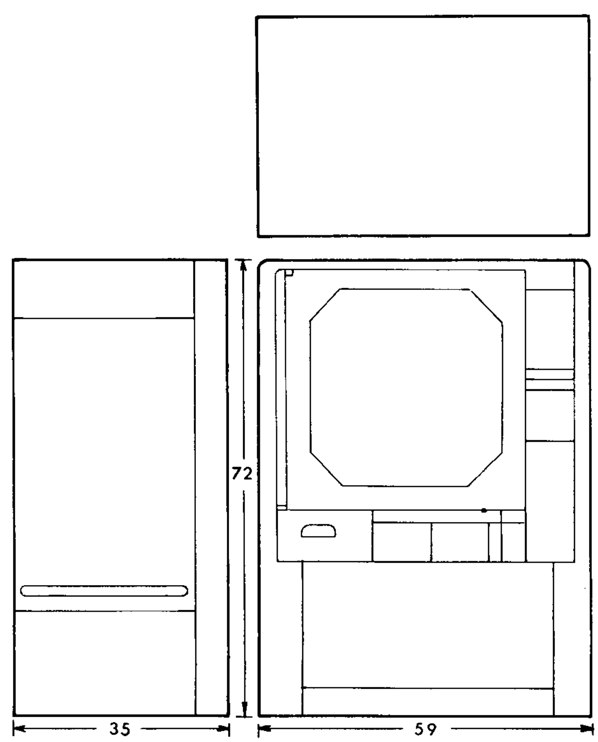
Crosswire Traverse: 12 seconds maximum for full traverse.

Electrostatic Copier: Projected light on the platen has overall deviation of 5% maximum. Copy processing time—30 seconds.

Print Paper Capacity: 6.5 inches diameter roll, 22½ inches wide, 300 copy capacity.

Radio Interference Suppression: Conforms with MIL-S-11748.

Shipping Weight: 2,860 pounds.



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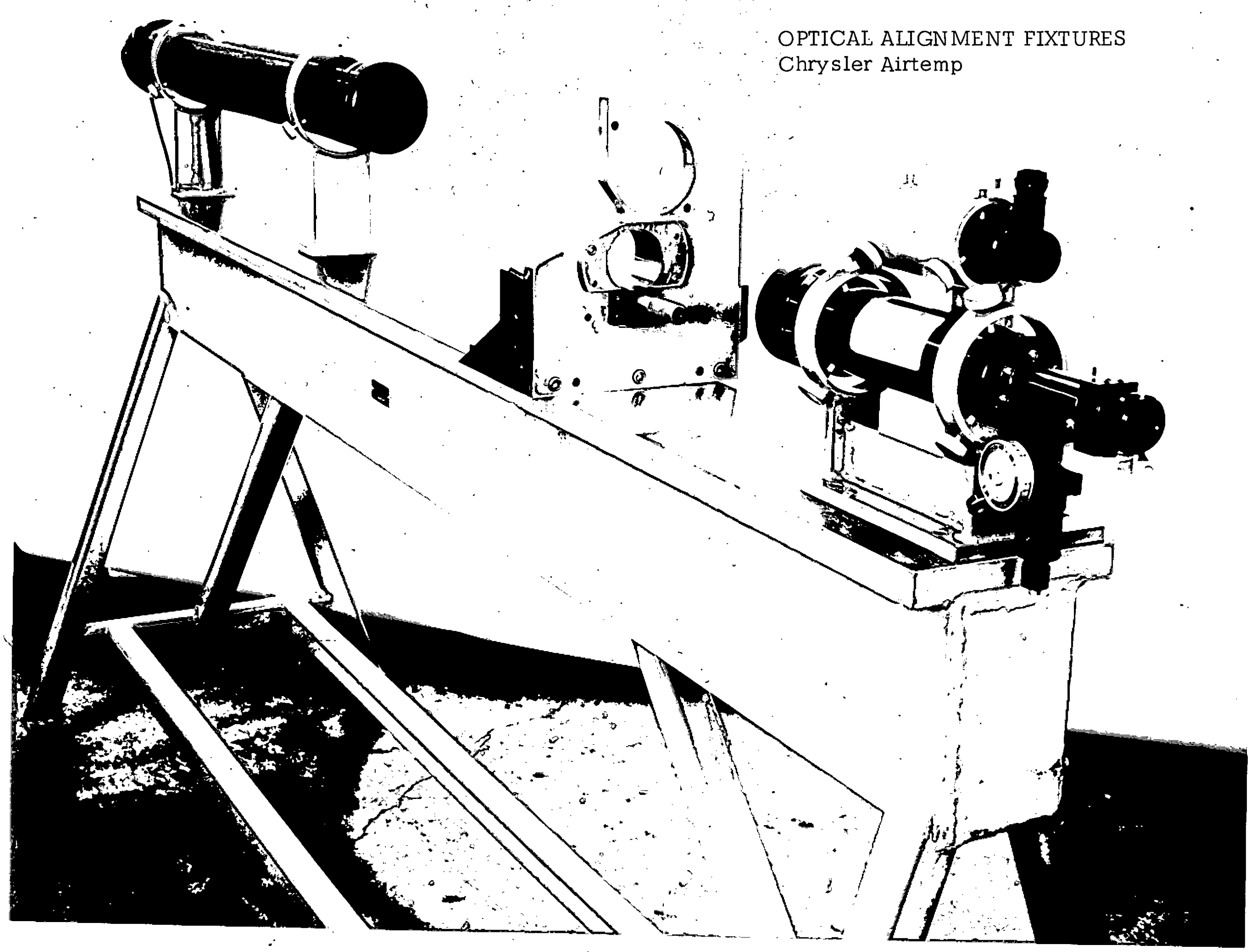
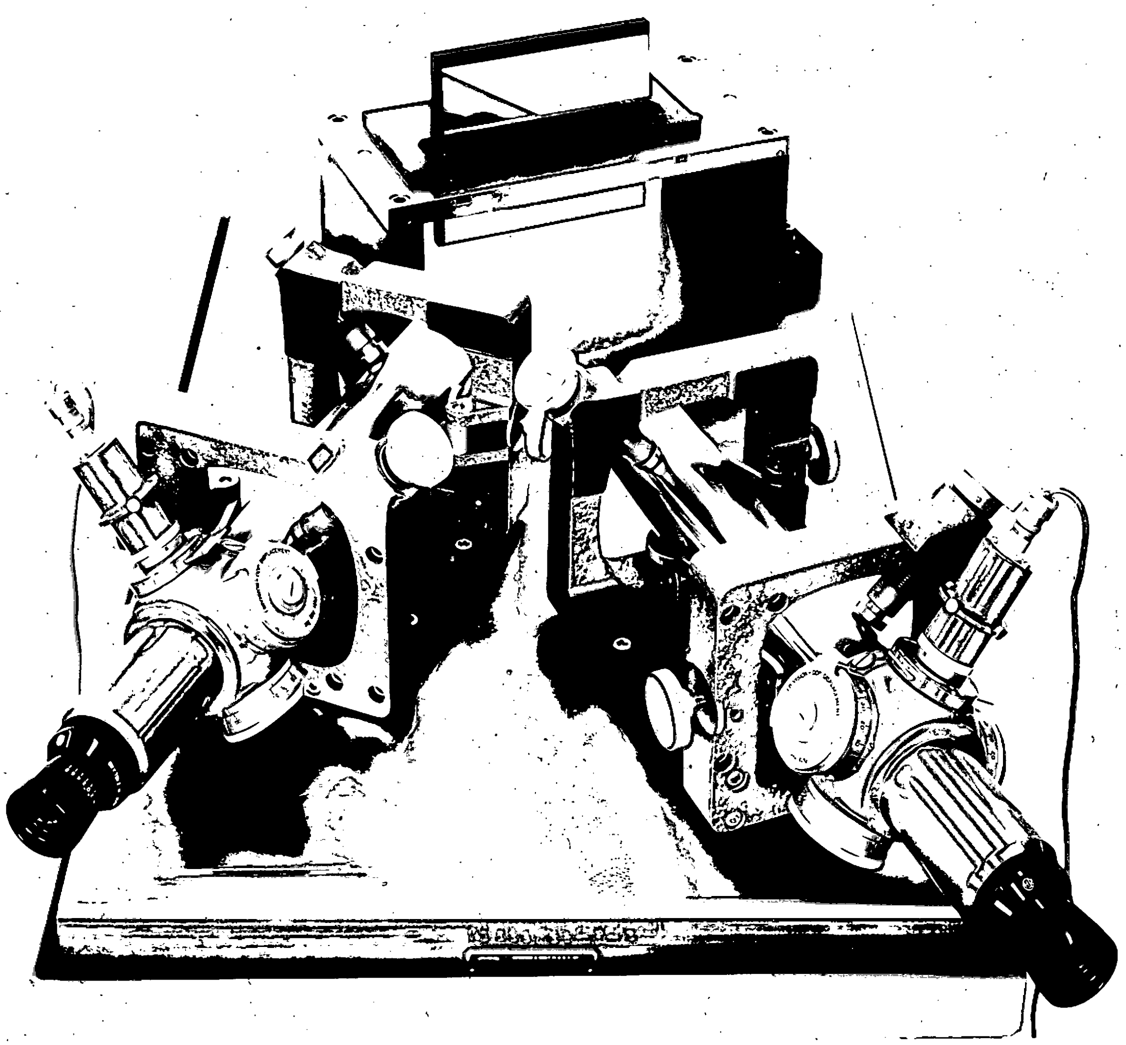


OPTICAL ALIGNMENT FIXTURES
Chrysler Airtemp



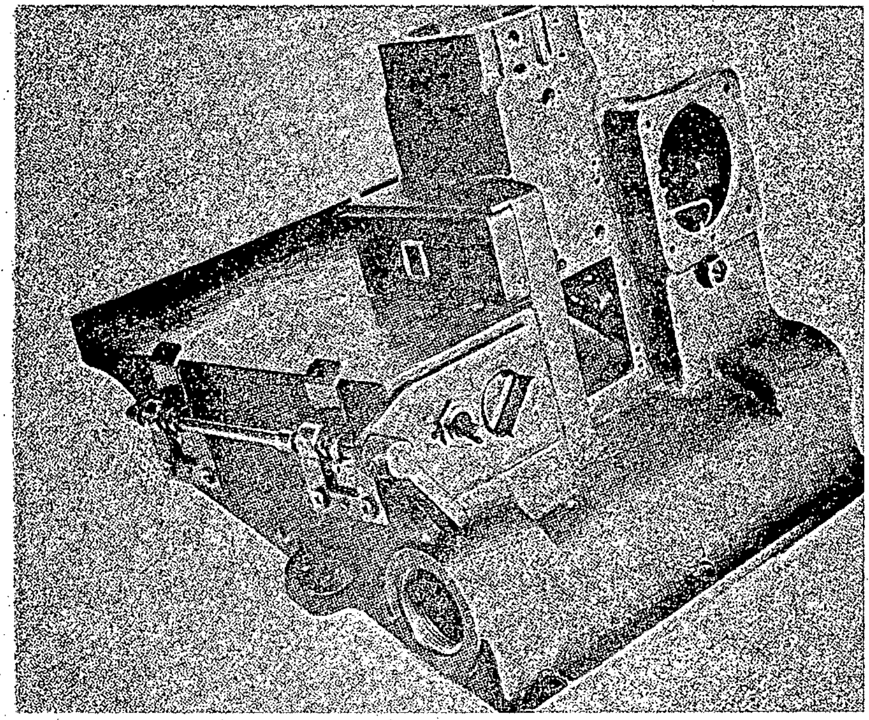
CALIBRATION UNIT, INFRA-RED PICK-UP
Chrysler Airtemp

Creative Engineering for Industry

[redacted]

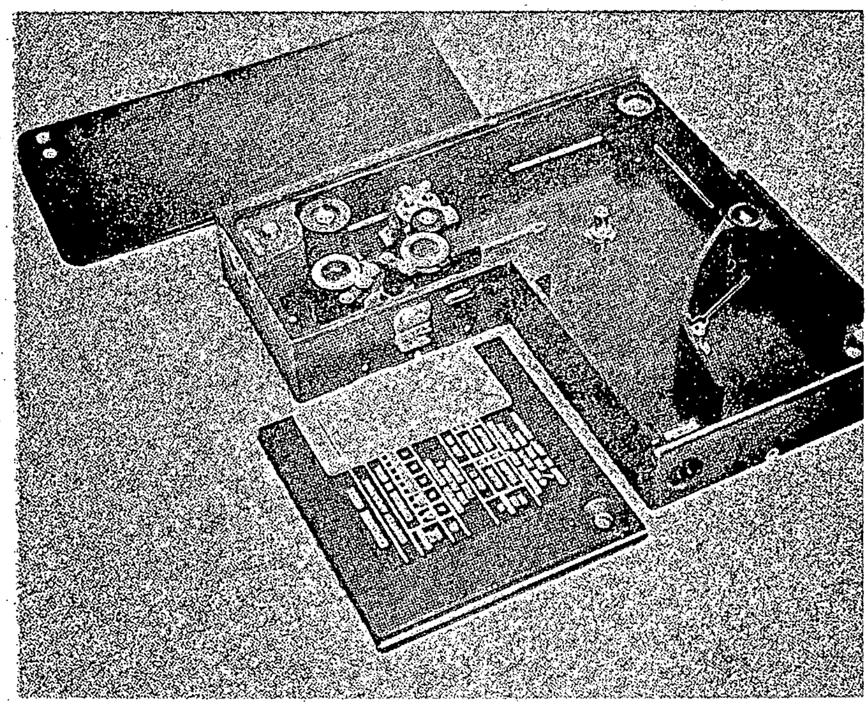
MOBILE TELEVISION CONTROL ROOM

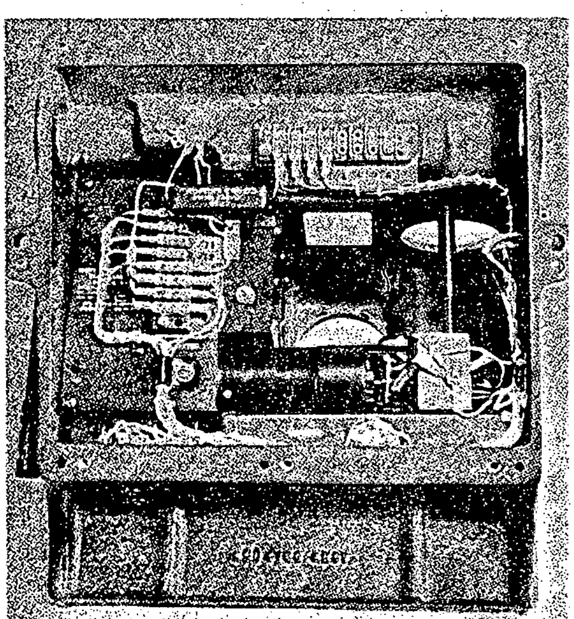
A compact mobile television control room designed and fabricated [redacted] in cooper STAT with an electronic manufacturer's representative for WFLD-TV, Chicago. This mobile unit easily passes through any normal door and can be transported in a standard-sized station wagon. It requires only one operator, yet provides full recording of television programs. This development is only one of [redacted] STAT [redacted] accomplishments in the audio/video enginee STAT field during its many years of experience.



RECORDING CAMERA FOR F107 AIRCRAFT

This 16mm Recording Camera was developed and prototypes fabricated by Pollak and Skan, Inc., engineers for use with a Universal Sight Head. Equipped with an automatic exposure control device, the camera is designed to provide maximum reliability and a minimum size and weight. Operating at 32 frames per second, the camera does not require the pilot's attention at any time in flight. The f/2.5 lens has a focal length of 25mm. The camera is equipped with a removable magazine with a capacity of 100 feet of film and contains a film footage indicator, magazine heater and thermostat.





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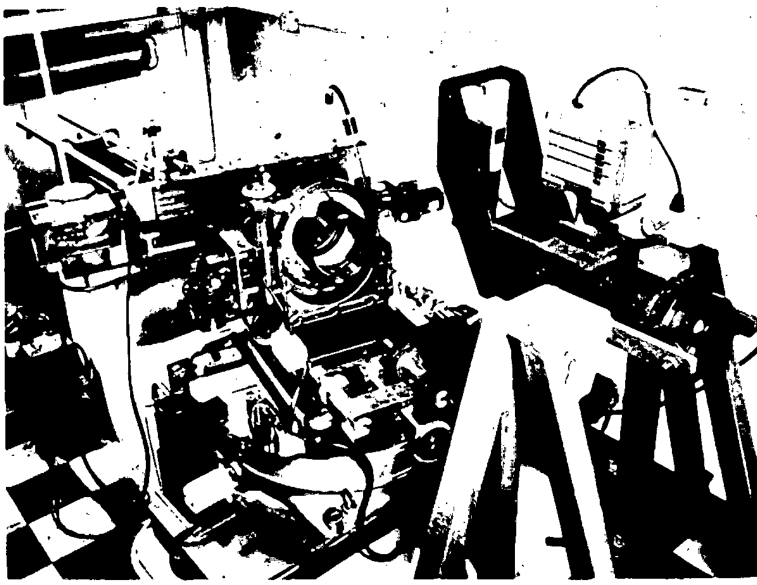
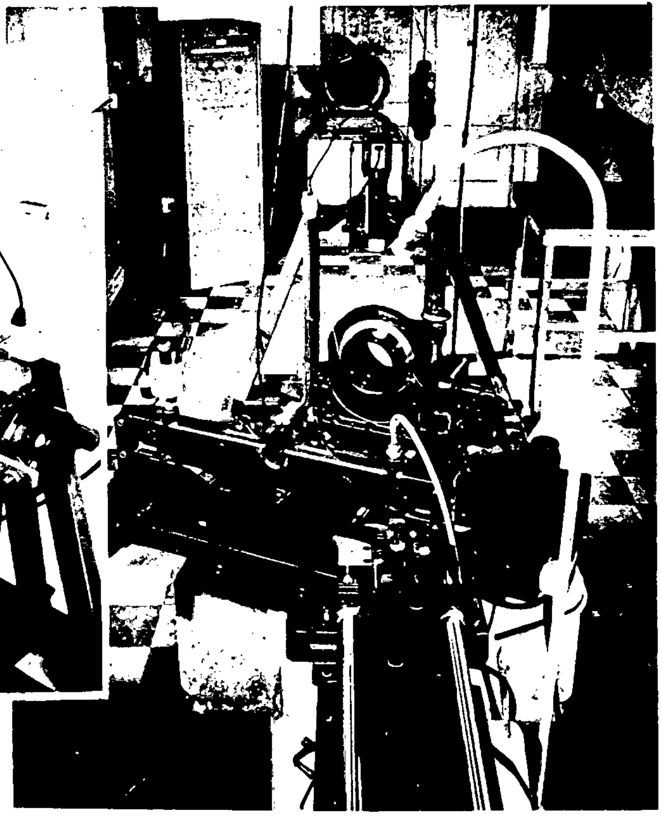

These photos reveal the intricacy of the equipment

SPECIAL CAMERA DEVICE FOR TESTING AERIAL CAMERA LENSES

[redacted] designed and fabricated this unusual device for production testing of aerial camera lenses. Normally, this process is very time consuming. With this automatic device, which photographically records the test data, lenses can be checked quickly and accurately. Included in this testing equipment are a number of important components; a parabolic mirror-type collimator, electronic flash unit, nodal slide for the lens and film holders, automatic recording camera, alignment telescope, microscope slide and remote control panel. This complex testing device indicates the scope of the creative resources available [redacted] for solving industrial and military engineering problems. STAT

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[redacted] STAT

NUMERICAL CONTROL SYSTEM FOR
A TUBE BENDING MACHINE

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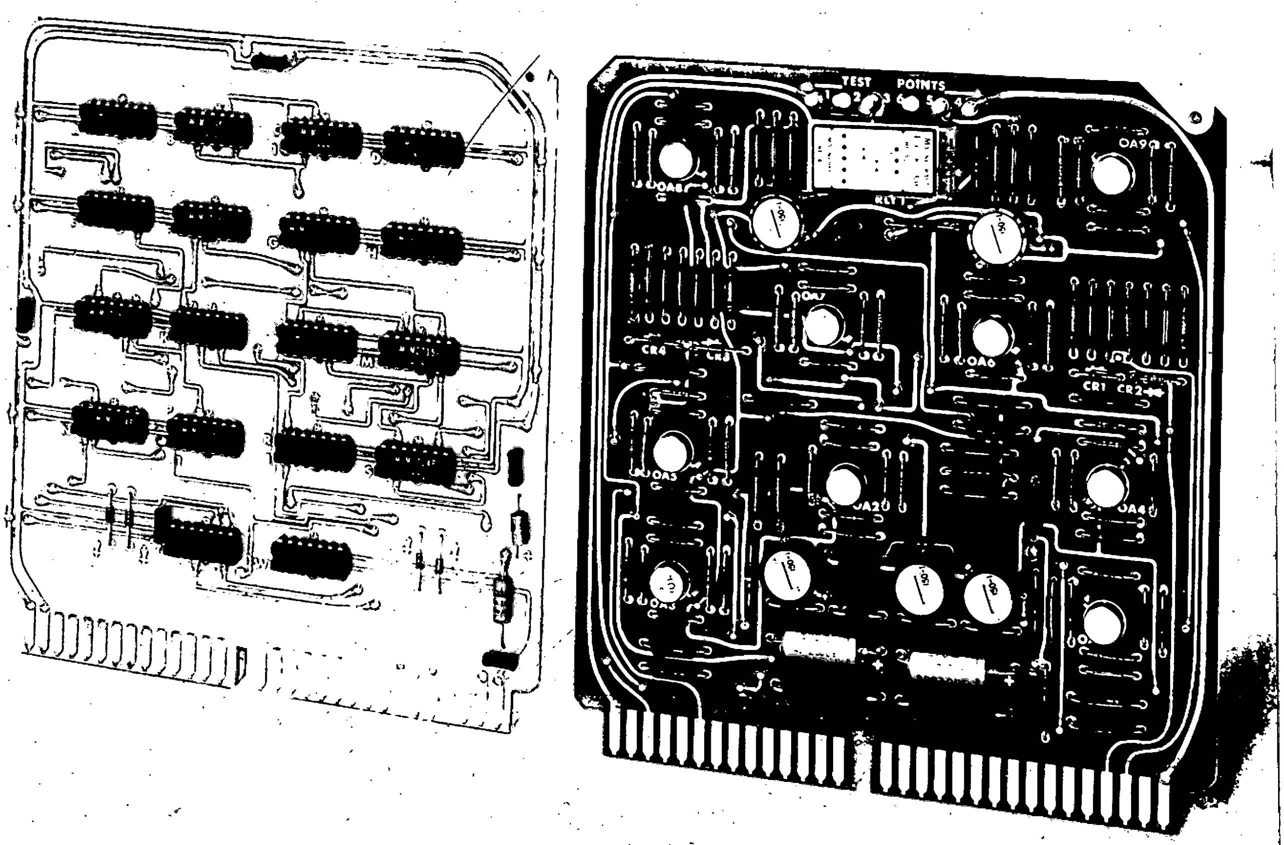

NUMERICAL CONTROL SYSTEM FOR
A TUBE BENDING MACHINE

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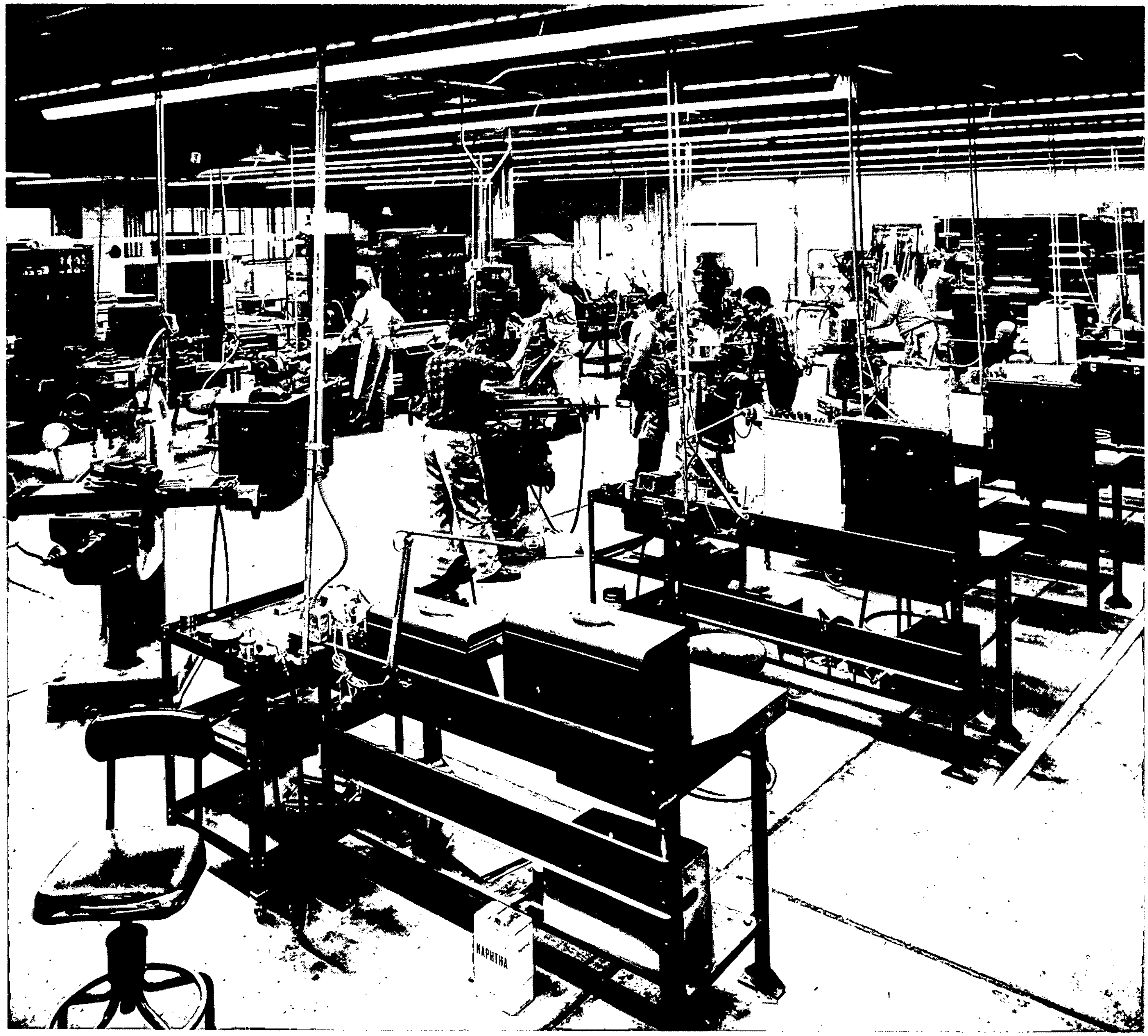

Model shop facilities
are complete . . . here
is a partial view

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Part of the drafting room facilities at

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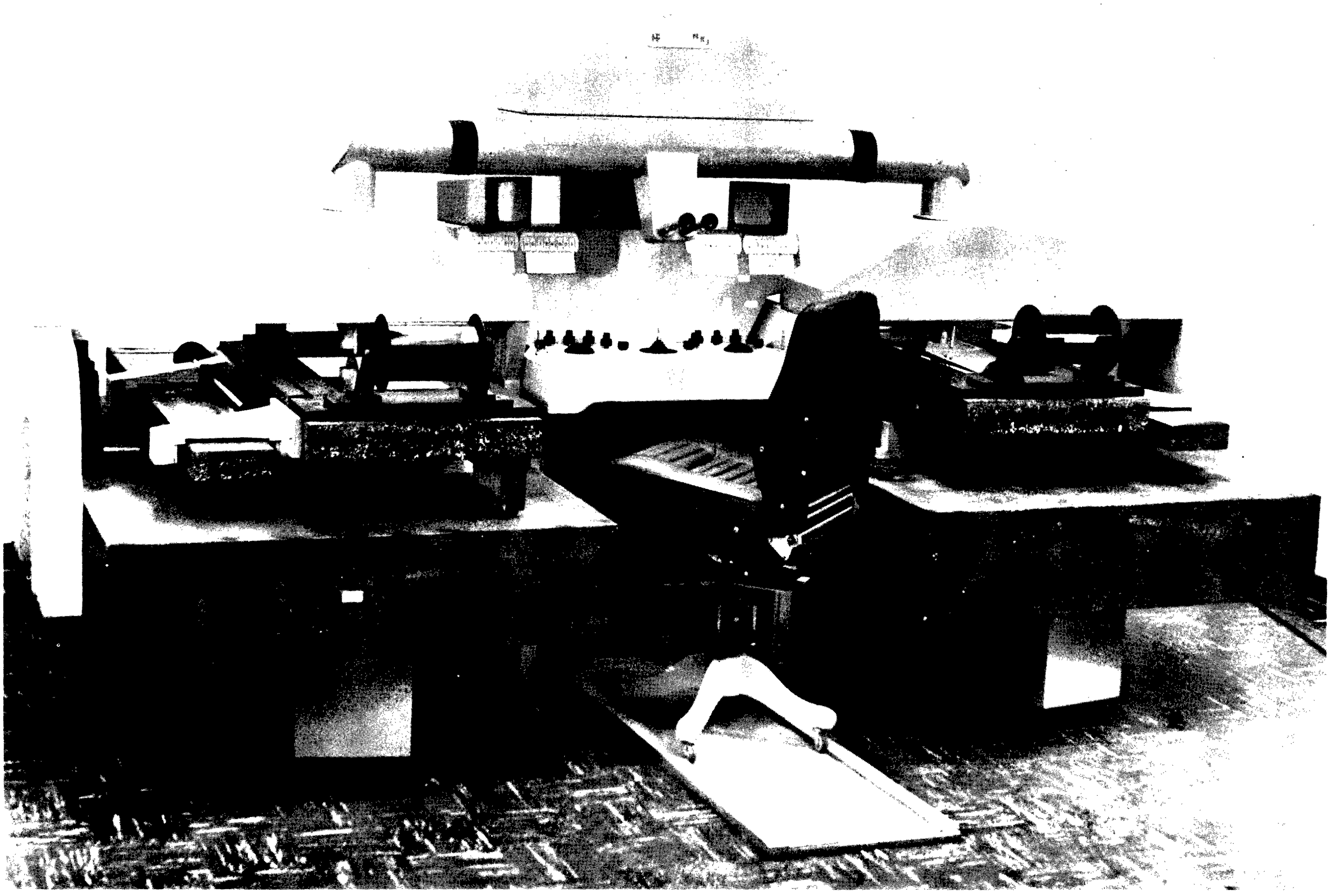

OPTICAL SPECIFICATION NO. 2
Ref: OS-2-302-15/18
JOB 302 April 5, 1967

DESIGN SPECIFICATIONS FOR THE OPTICAL SYSTEM FOR AN ULTRA-HIGH PRECISION STEREO COMPARATOR

1.0 Introduction

This specification covers the performance requirements for the detailed design of the optical system for a binocular microscope high precision stereo comparator. Note that the feasibility of the optical system has already been established and that the actual working equipment will be fabricated through a follow-on procurement.

The optical design effort must concern itself not only with the optical specifications of the system, sub-systems and components but with tolerances on the optical element figure and location. Additionally, the design effort must include the mechanical components directly related to the optics and must consider the practicability of the design to be fabricated. Further, the design effort much include an estimate of a fabrication cost and delivery time.

The end product of this design effort will be the completed detailed design of the optical elements including the necessary drawings, specifications, and test requirements to effect the follow-on procurement.

One possible configuration of the optical elements as related to the stereo comparator instrument as a whole is shown STAT [redacted] drawing No. E-4123. A photograph of the mock-up of the instrument is included for reference purposes.

It is desired that the vendor exercise maximum ingenuity in developing the required optical system. While the system described in the specifications is believed to be workable, it is possible that individual designers may prefer to place the components in a different order or perhaps may have different concepts for the detailed design of the various individual components. In order to accommodate the maximum degree of initiative on the part of the optical designer it is planned to provide for maximum flexibility in the interfacing elements.

Note that it is essential that the design prepared by the vendor be within the state-of-the-art fabrication.

The stereo comparator instrument is being designed at the purchaser's facility concurrently with the optical design effort. Thus frequent communication will be required between the purchaser and the vendor to be sure that there are no interfacing problems.

The goal of the design effort is to produce a detailed optical design which is sufficiently complete that no further design effort is required before the fabrication of the optical and associated hardware.

2.0 Concept

The high precision stereo comparator is an instrument for automatically providing stereo viewing from a dissimilar geometrically stereo pair of photographs. These photographs are in the form of film negatives transparencies or positives. The purpose of the optical system is to optically transform the two differing photographic views and make them compatible for stereo viewing. The various elements of the optical train will be operated through servo motors and a scanning system to provide the transformed views to the operator of the instrument. Each photograph will be mounted on a movable stage between which sits the operator at a control console.

The horizontal separation of the centers of the two stages is 75 inches and they are 16 3/4 inches below the operators eye level. Two equivalent, but of opposite hand mechanically, optical systems, (one for each stage) bring the images of the film to the center of the console and present them to the operator. The images are observed through binocular microscope eye pieces.

3.0 Scope

The optical design effort is to include the detailed design of an optical system compatible with the requirements of the ultra high precision stereo comparator. In addition to the complete detail design of the optical elements it will be necessary to provide system ray traces illustrating the various parametric values, aberration data, spot size of MTF data, detail and assembly drawings, calculations and other pertinent data required by the purchaser. In addition, test and inspection data and any other pertinent information will be required from which, at a later date the optical hardware can be fabricated, assembled, tested and used as part of an operating stereo comparator.

4.0 Deliverable Items

Twelve copies of all documents prepared as part of the optical design effort are to be delivered to the purchaser. This includes, but is not limited to the items described under Section 3.0 Scope and the attached schedule of deliverable items.

Part of the design effort must include the preparation of a cost estimate for the fabrication of the optical hardware, together with an estimate of the time schedule required to build the system.

5.0 Schedule

The total time schedule for the preparation, processing of design proposal, and for the performance of the optical design effort provides from eight to nine months.

5.1 The technical proposal and the price quotation for the optical design effort is to be delivered as stated in the attached proposal schedule. The proposal may be in outline form but must include a detailed discussion of any design problem areas. A non-detailed discussion of the overall system proposed should be provided to indicate the method of attacking the design problem and to show state-of-the-art familiarity with the various components.

5.2 Upon receipt of the vendor proposals, [redacted] will respond STAT within three weeks and will notify technically acceptable vendors of intention to visit their facility to discuss details and review capability, or invite vendors to an initial subcontract discussion, or notify vendor of reasons for unacceptability.

5.3 During this period after completion of 5.2 above, any revisions to the specifications, suggested by the vendor, will be discussed. These revisions will be incorporated as part of the firm specification, subject however, [redacted] STAT approval.

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5.4 The detailed optical design is required to be completed in 6 months after award of the contract. [redacted] expects to work closely with the contractor during the design effort to insure that there would be no delay due to interfacing problems or to lack of understanding of the overall requirements. STAT

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6.0 Design Criteria

The essential criteria in evaluating the various optical design systems that may be proposed will be the level of optical performance achieved. Secondary criteria will include the cost of the follow-on optical hardware, the ability of the optical system to remain in adjustment during normal use, the cost of the design effort, the degree of departure from state-of-the-are design concepts and the timely performance of the design effort.

7.0 General Optical Requirements

The complete optical system consists of two substantially identical optical channels, one for each of two stages. One channel is provided for each eye and views the respective stage carrying the stereo photographs.

Each optical train consists of the following components: listed in provisional order. Note that the component arrangement is not mandatory, however, the system must perform in the specified manner.

7.0.1 An illuminating system for each stage equipped with a zoom condensing system.

7.0.2 An objective lens for each stage.

7.0.3 A reticle injecting beam splitter for each stage together with reticle size, shape, azimuth control, and illuminating optics.

7.0.4 A zoom system with a continuously variable magnification range between 1X and 20X for each stage.

7.0.5 A continuously variable anormorphic system giving an expansion range of 1:1 to 1:2 in any azimuth, for each stage.

7.0.6 An image rotating system capable of providing continuously variable image rotation of 0 to 360 degrees, for each stage.

7.0.7 Image extraction beam splitters for camera tube readout. Two cameras for each stage.

7.0.8 A parfocal prismatic section for switching between four possible viewing modes.

7.0.10 Additional relay lenses, field lenses, stray light baffles and stops, etc. as required.

There are certain mechanical constraints for the stereo comparator as a whole. These contraints must be accomodated by the optical design effort, however, significant departures from the geometry of the system must be approved Such changes will be given STAT
prime consideration where the optical advantage is high.

7.1 Magnification

The magnification of the overall system is defined as the angular subtense at the eye of the final image formed at infinity, divided by the angular subtense of the object when placed 25 centimeters from the eye.

The magnification must be continuously variable from 200 X. A 10 X eye piece is required and this provides that the magnification range for the zoom system be 1 X to 20 X. In the event that a 20:1 continuous zoom ratio is not considered feasible by the optical vendor a step system would be considered. This system could consist of a 1 X to 10 X continuous zoom ratio with a fixed 2 X magnifier that could be switched in and out of the optical train. Thus the combination of the fixed switching lens system and the 10:1 zoom would give the necessary 20:1 overall zoom ratio.

Note that there is a complicating factor for the magnification range, introduced by the anamorph system, when the anamorph is set at 1:2 expansion, then the maximum magnification attained by the system on the expanded axis will be 400 X.

7.2 Resolution

The optical system is required to exhibit the highest resolution capable of practical attainment. When this is considered and evaluated with the requirements of the system as a whole, some compromises may have to be accepted by the purchaser. This situation has been anticipated and no unreasonable requirements have been knowingly specified.

The design goal for resolution will be 80 line pairs per millimeter at 10X, decreasing linearly to 1000 line pairs per millimeter at 200X.

Consistent with these data the depth of focus must be maximized.

7.3 Eye Piece Angular Field

The total angular field at the eye piece image is to be at least 40 degrees, relating back to the object field as a diameter of at least 18 millimeters at a magnification of 200X.

7.4 Distortion

The final image must be as close to aberration free as possible, within the resolution limits of the system. The distortion of the system must be held to less than 1 percent over the central 90 percent of the field diameter as seen by the eye at all magnification settings. Furthermore, the objective field must be flat to within the photographic depth of field over the central 70 percent of its diameter for as large a magnification range as possible.

Note that then the anamorphic ratio is set at 2:1, then the maximum magnification along one axis may be as high as 400 X.

Under these conditions also, the distortion and and flatness requirements must be optimized.

Over the balance of the objective field and beyond the magnification limits specified above, the objective field must appear flat to the eye within the visual accomodation range.

7.5 Anamorophic Expansion

The variable anamorphic expansion range of 1:1 to 1:2 must be attainable in any azimuth. It is recognized that in some systems the anamorphic correction range of 1:1 may be not exactly attainable. A minimum ratio within 1 percent of the 1:1 value will be acceptable.

7.6 Reticle

One of the functions of the comparator is to measure the distance between two points in the film plane.

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In order to accomplish this, an optical fiducial mark must be provided in the viewing optics, whose position relative to the film plane must remain fixed to within 1/4 of a micron, while adjustments are made to the zoom, anamorph, image rotator and objective focusing system. The reticle provides this optical fiducial mark.

To meet the stability requirement, the reticle forming optics, its beam splitter and the objective lens system must be in one rugged mechanical unit. The image of the reticle as seen by the eye should be variable in brightness and variable in size from defraction limited to four times the apparent diameter of the airy disc at any magnification setting.

The reticle image must be closely circular for all settings of the anamorph and with constant angular size for all zoom settings. Note that when the reticle image is of larger size than in the defraction limited condition, it must have a sharp edge.

7.7 Illumination

The stereo comparator is arranged for illuminating the stage (film) from below.

A six inch diameter vertical hole is provided through all the base structures under the film platen. This hole is about 22 inches long and terminates in the steel structure that supports the granite stages.

Access to the lower end of this hole is provided through a 12" x 12" opening in the top and side of the rectangular steel structural beam.

The light source can thus be located outside of, underneath the granite base structure, while the optical elements may be installed in the vertical six inch hole.

As the system magnification is varied by either zoom or anamorphic systems the final image field must remain at an apparent constant brightness. It is presumed that the illumination condenser system will require zoom capability.

The brightness level of the final image must be such that the eye can distinguish a difference between optical densities in the film differing by units of less than 0.1 in the range of 0.0 to 3.0.

The color temperature of the light source must exceed 3500°K at all intensity levels.

The light source must be provided with the necessary means of eliminating heat at the film plane.

The maximum local temperature of a 3.0 density film must be less than 8°C above the ambient air temperature. To accomplish this, cooling may be recommended by the vendor at the film plane as well as at the light source. Additionally infra red filters with cold or hot mirrors may be required in the optical path as part of the optical design.

7.8 Image Rotator

The image rotator must be compatible with the balance of the optical system. In addition it must be capable of providing continuous image rotation through 360 degrees in either direction.

7.9 Monitor Beam Splitter

A beam splitting system must be provided in the optical path between the image rotator and the eye pieces. This is for the purpose of extracting two images for scanner readout for each stage. The final images of the system are thus formed on two vidicon targets and two image disector tubes adjacent to the eye pieces.

The beam splitter in each of the main optical paths removes approximately 10 foot candles of illumination. This illuminance is divided into approximately 8 foot candles for the image disector tube and approximately 2 foot candles for the vidicon camera. The real image presented to the eye piece, which is at least 18 millimeters in diameter, is suitable for the camera targets.

7.10 Beam Switching

The main optical views presented to the left and right eye pieces must be arranged for switching between four modes of operation. These modes are as follows:-

7.10.1 Both eye pieces must be able to view only the left hand field, i.e., the image presented by the left hand stage.

7.10.2 Both eye pieces must be able to view only the right hand field, i.e., the image presented by the right hand stage.

7.10.3 Each eye piece must be able to view only a single field. The left hand eye piece must view the image from the left hand stage while the right hand eye piece views only the image from the right hand stage.

7.10.4 Each eye piece must be able to view only a single field. The left hand eye piece must view the image from the right hand stage while the right hand eye piece views only the image from the left hand stage.

7.10.5 The four modes above must be parafocal, the images presented to each eye must be of equal apparent brightness. In addition, the images formed during the four modes above must retain the same rotational sense as the object field. Further, when the image rotator is in its 0 set position, i.e., images not rotated, the left hand edge of each object must be seen as the left hand edge of the corresponding final image. Thus the operator would see a right reading image.

7.11 Eyepieces

The eyepieces must be 10 X magnification and must be arranged in their supporting assembly so that all necessary adjustments may be convenient for operator use.

The requirements must include the following items:-

7.11.1 The interpupillary distance must be continuously adjustable between 50 and 75 millimeters.

7.11.2 Eye relief must be 20 $\pm$ 2 millimeters.

7.11.3 The sight angle of the eyepieces must be arranged so that the operator is looking downwards at an angle of 15 degrees below the horizontal.

7.11.4 Independent and continuous adjustment of one eyepiece must be provided over the range $\pm$ 1 degree vertically. This applies to the sight angle in 7.11.3 above.

7.11 4 The line of sight, axes of the eyepieces must converge with an included angle of about 5°.

7.11.5 The eyepiece mounts must be provided with independent focussing.

8.0 General Mechanical Requirements

The anticipated arrangement of the stereo comparator as a whole is shown by the reproduction of the photograph included with these specifications. The operator is seated approximately at the center of the machine looking towards the control panel into a pair of eye pieces at head height. On each side of the operator are the two stages carrying the film and the objectives for the optical system.

8.1 Dimensions

The horizontal separations between the centers of the two objectives is 75 inches. The binocular eye piece assembly is located halfway between the two objectives, and the operator will be seated slightly back from the straight line joining the two objectives.

The optical path must rise a vertical distance of 24 1/2 inches from the film plane before being reflected towards the operator.

The eye piece exit pupils are to be located horizontally 9 1/2 inches towards the operator from the center line connecting the two objectives. Also the eye piece exit pupils will be about 8 1/4 inches below the horizontal center line of the optical system.

The horizontal optical path between the objective lens systems and the eye pieces does not necessarily have to be a straight line. If additional length is required to accommodate the necessary optical elements in the horizontal or vertical legs, then the inter-connecting system may be folded or otherwise extended to provide the longer optical path. Note that the arrangement selected must be approved [redacted] since there may be interfacing problems. STAT

The diameter of the optical path connecting the objective lenses with the eye pieces should be kept as small as possible. Three inches diameter has been suggested as a suitable size. Minimizing this number (but without compromising the optical design) assists the mechanical designer in that the supporting structure can be kept reasonably small and light.

8.2 Image Wander

During operational adjustments of the Zoom, Anamorph, Image Rotator elements etc., the Wandering of the optical axis of the system should be kept to less than $\pm$ 2 spot diameters of the diffraction limited reticle spot in the final image. The reticle injection point has deliberately been kept as close as possible to the film plane in order to minimize wander between the reticle and the film object. The maximum allowable wander between the reticle image and the film object position must be less than $\pm$ 1/4 of a micron. Wander at this point causes error in the readout of the film positioning system.

Optical wander elsewhere in the system does not effect the position of the readout of the stages, but does create problems for the observer. While adjustments are being made, the particular film image in the center of the field of view should remain substantially at the center.

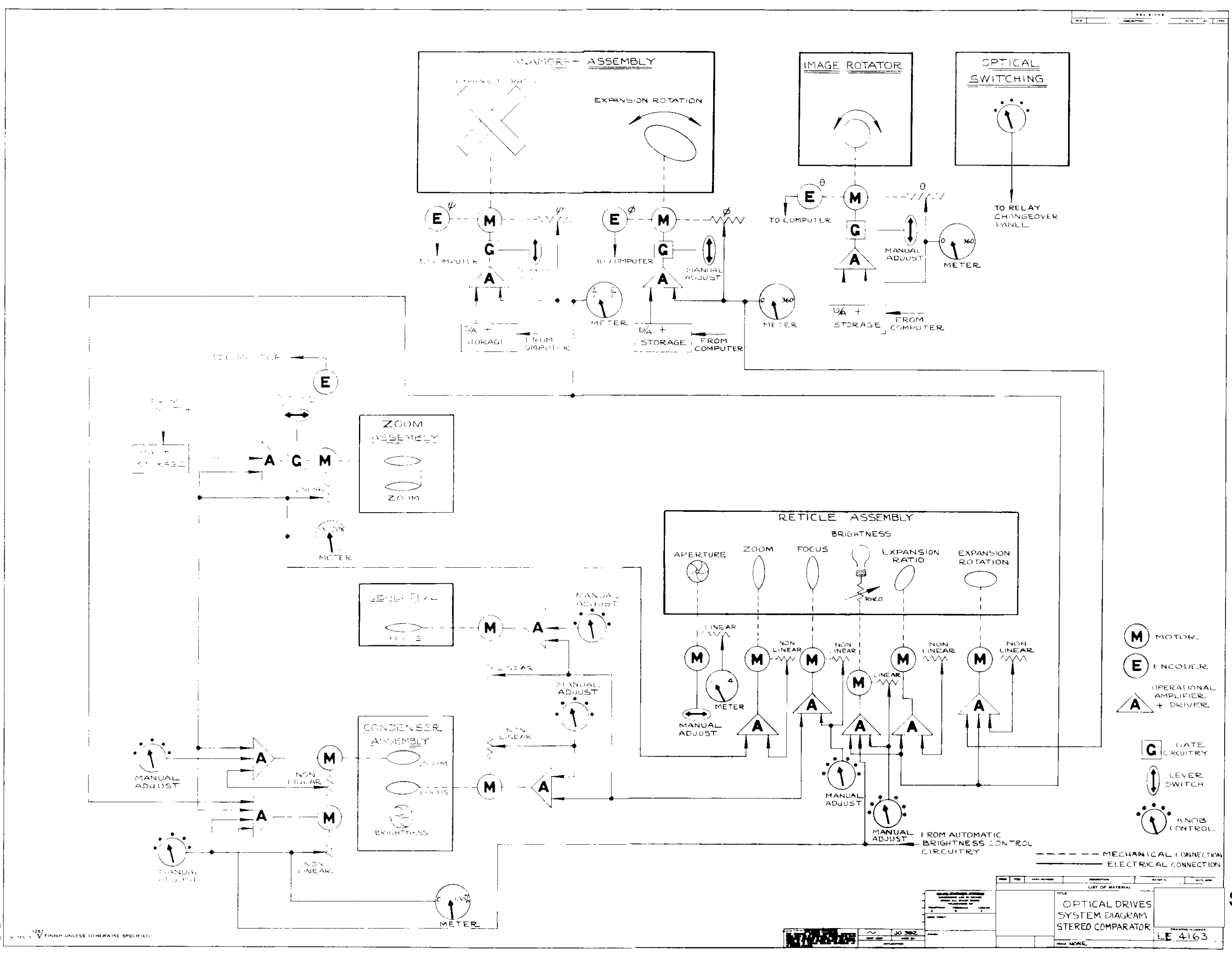
In order to further minimize the effect of image wander on stereo fusion, it is preferred that the field stop be apodized such that its edge is not sharp but subtends an angle of about one degree to the operator's eye.

8.3 Optical Drive

Practically all of the optical elements will require some form of mechanical drive. The drives will consist of electric motors, suitable mechanical linkages, and the necessary ways upon which the optical elements travel by the action of the drives.

[redacted] will provide the motors for the drives and the servo mechanisms and feedback devices that link the moving elements with the motors. STAT

The vendor is to supply the opto-mechanical design of the assemblies and to provide the design of the equipment necessary to interface with the driver and the servo components.


ANAMORPH ASSEMBLY
EXPANSION ROTATION
IMAGE ROTATOR
OPTICAL SWITCHING
TO COMPUTER
MANUAL ADJUST
METER
D/A + STORAGE
FROM COMPUTER
TO RELAY CHANGEOVER PANEL
ZOOM ASSEMBLY
ZOOM
RETICLE ASSEMBLY
BRIGHTNESS
APERTURE
FOCUS
EXPANSION RATIO
LINEAR
NON LINEAR
CONDENSER ASSEMBLY
MANUAL ADJUST
FROM AUTOMATIC BRIGHTNESS CONTROL CIRCUITRY
MOTOR
ENCODER
OPERATIONAL AMPLIFIER + DRIVER
GATE CIRCUITRY
LEVER SWITCH
KNOB CONTROL
MECHANICAL CONNECTION
ELECTRICAL CONNECTION
OPTICAL DRIVES SYSTEM DIAGRAM STEREO COMPARATOR
LE 4163

STAT

Various methods of designing the optical drive servo system are presently under consideration [redacted] Full flexibility STAT
is allowed the vendor (subject to [redacted] approval) to utilize STAT
any proven design philosophy in establishing the methods to be used for adjusting the optical elements. Detailed design considerations should include not only the conventional movement of the glass lens elements by mechanical means within the package designed by the vendor, but also the possibility of using electronic position transducers as function generators with servo position controls, to operate the optical elements. The vendor would design a means of mounting the motors and the transducers, a means of mounting the lens elements, and a ways upon which they would move and a provision for connecting the motors to each of the moving lens elements.

[redacted] would provide the servo electronic linkages and would STAT
design the function generator characteristics of the electronic transducers. These transducers might consist of linear potentiometers characterized for the mathmatical functions required by the optical system.

The final choice of overall system would be based on the optical performance and the degree of technical complication and fabrication difficulty expected. The optical designer must establish all parameters for the required performance of the drivers and servo system.

8.4 Mounting Structure

[redacted] will provide the design of a three-section mechanical structure upon which the optical hardware will be mounted. The vendor will provide the design of the optical elements in the form as assemblies integrated mechanically as required and ready for mounting to the bridge sections furnished [redacted]. The vendor must include in his design effort the provision for adjusting the mountings so that the optical elements may be properly aligned in the bridges at the time of fabrication of the overall stereo comparator assembly. STAT STAT

The optical design vendor must furnish outside dimensional data for his design in a timely manner so that the interfacing information may be used [redacted] STAT

The bridge will be arranged with one section attached to each stage and a central eye piece section attached to the main base frame of the stereo comparator. The three-piece design is necessary to eliminate thermal expansion problems and mechanical shock problems between the two stages and the eye piece arrangement.

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The central eye-piece section will be connected to each of the stage sections by means of short flexible joints which would be essentially dust covers and would not contribute to any structural rigidity. In order to satisfy this mechanical isolation feature of the bridge structure, the light path in the area of the flexible joints would have to be substantially collimated.

8.5 Film Plane Focussing Adjustment

There is a requirement for film plane focussing in each optical leg. The objective and reticle assembly must be capable of vertical movement over a distance of about $\pm$ one eighth of an inch to provide for focus on the film plane. In addition there must be a fine focus arrangement which would cover a vertical range of $\pm$ 1/32" to accommodate focus adjustments in sub-micron increments.

Note that the relation between the reticle and the selected viewing point on the film object plane must not wander more than $\pm$ 1/4 of a micron during fine focus adjustment.

8.6 Environmental Conditions

The equipment must be designed to operate in a laboratory environment. The nominal room temperature would be 72° Farenheit with a possible variation of plus or minus 5°. It is anticipated that ordinarily during actual use of the stereo comparator, the temperature will be maintained at 72° Farenheit plus or minus 1.5° Farenheit.

The normal Relative Humidity of the laboratory would be 55% minus 5% plus 15%. There may be possible traces of photographic processing vapors present. The equipment must be inherently capable of withstanding storage temperatures from 20° Farenheit to 120° Farenheit and humidities from essentially zero to 90% Relative Humidity. Under these latter conditions the equipment would not be required to be operable.

8.7 Shipping and Assembly

For the basis of the optical design it is anticipated that the optical bridge elements which immediately interface with the optical hardware would be supplied to the optical vendor for assembly. Thus the assembly and tests of the various optical elements would be performed in the plant of the optical vendor. These resulting rather large sub-assemblies would then be shipped to the stereo comparator assembly site for installation.

In this present design only, contract, we are not directly concerned with field problems. However, the optical designer must bear in mind that this type of arrangement will exist and the design philosophy must accommodate the type of field installation normally encountered in practice.

[redacted] STAT

10 April 1967

Gentlemen:

[redacted] STAT
is soliciting quotations for the detailed design of the optical system as described in specification OS-2-302-15/18 enclosed. The optics, and mechanical mounting are part of a present program to develop an ultra high precision photogrammetric instrument.

Please find enclosed a bid package, including the technical exhibit, instructions on how to prepare your quote, schedule and terms and conditions.

[redacted] requests that you acknowledge receipt of this package and declare your intentions to quote within seven days after receipt of this request, or return the entire bid package to requestor. STAT

[redacted] anticipates a six month design effort by the selected vendor beginning on or about 21 May 1967. Therefore, technical proposal and price quotation will be required for review on or about 1 May 1967. STAT

Please state any exceptions or deviations from the technical specifications or delivery in your offer.

If you require any assistance, please contact [redacted] Contracts Administrator, [redacted] Technical questions will be referred to [redacted] Program Director, and timely answers are assured. STAT STAT STAT

Respectfully,

[redacted] STAT

WJW:lab

enclosures

PROPOSAL SCHEDULE

Please furnish quotations* as specified below on or about 1 May 1967.

1. If you are unable to quote, please so indicate within seven days and return the Bid package.

2. Technical Proposal
   12 copies

3. Price Quotation using Forms DD633-4 (sample enclosed)
   5 copies

4. Minimum Financial Information
   Financial Statement acceptable
   3 copies

5. Management Proposal
   5 copies
   (Include Resumes of Key Personnel)

6. Proposed Delivery Schedule
   (With major milestones flagged, e.g., "design freeze, preliminary ray trace, sub-assembly drawings," etc.)

This proposal will be supported by twelve (12) copies of a technical proposal, including such schematic and/or block diagrams as may be required, to illustrate clearly the manner in which it is proposed to conduct the design project.

A complete quotation with regard to this procurement will consist of two parts, i.e., a price quotation and a technical proposal. Both parts are required for this quotation to be responsive.

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*THIS IS NOT AN ORDER. This request does not commit [redacted] [redacted] to pay any costs incurred in the preparation or the submission of the quotation, or to procure or contract for supplies and services.

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Information on the following is required to be submitted by the Quoter as a part of his proposal:

a. A description of the Quoter's understanding of the scope of the work as shown by the scientific or technical approach proposed. This will include (i) an outline of the major factors to be investigated, (ii) the general approach to the investigation of each, and (iii) the extent of the total work anticipated.

b. A detailed engineering description of the item which will include any block diagrams or schematics illustrative of how it is intended to comply with the applicable specifications.

c. An outline by the Quoter of the problem(s) anticipated to be encountered in complying with the specification requirements together with the approach(es) to be applied in resolving such problems.

d. A full explanation of the reasons for any exception or deviation taken, identified with the specification and by paragraph within the specification. If no exception or deviation is taken, so state.

e. A statement by the Quoter on the general design characteristics of the item.

f. A statement of the availability and competence of experienced engineering, scientific, or other technical personnel. This shall provide a brief summary of the educational background and experience of key contractor personnel and amount of time to be assigned to this project.

g. A brief summary of the Quoter's experience or pertinent novel ideas in the specific branch of science or technology involved.

h. The Quoter's willingness to devote his resources to the proposed work with appropriate diligence. This will include a statement describing the proposed administrative assignments of the work within the Quoter's organization, and will indicate the organizational units to be assigned responsibility for the management of the proposed program and the supporting relationship of other administrative units.

i. Other information as considered necessary in the particular case - for example, an itemization of technical engineering aspects considered to be of such importance that any deviation or exception thereto would tend to exclude a prospective contractor from further consideration.

SCHEDULE OF DELIVERABLE ITEMS

OS-2-302-15/18

DESCRIPTION - SUMMARY	SCHEDULE
1. Preliminary Drawings Three sets Blueline prints	3 months after award
2. Drawings Two reproducible copies each Three sets Blueline prints	6 months after award
3. Test and Inspection Data Two reproducible copies	5 months after award
4. Detailed Specifications Two reproducible copies each Three Sets Blueline prints	6 months after award
5. Breadboards and Mock-ups One reproducible copy of drawings or data	7 months after award
6. Technical Direction Meetings as Requested by [redacted] at Contractor's Site Not to exceed three	
7. Progress Reports One reproducible copy Two copies	Monthly
8. Briefing Materiel	5 months after award
9. **Fixed Price Cost Estimate for Fabrication and Delivery of Hardware	6 months after award
10. **Hardware Schedule	6 months after award

STAT

**May be from other suppliers

Schedule of Deliverable Items (contd.)

The deliverable items as specified shall be delivered to:

STAT

Ref. OS-2-302-15/18

STAT

DESCRIPTION

1. Drawings, Preliminary

Layout Drawings (informal) describing near approximations of element configuration and relationship. Mechanical package configuration, mechanical restrictions and constraints. Preliminary specifications for the "system."

2. Drawings, Manufacturing

A complete set of manufacturing drawings, schematic and specification drawings to best commercial standards for such drawings. It is preferred that all engineering drawings be orthographic, third angle projection. A complete materiels and parts list, specifying all coatings, treatments, or special processes required to fabricate and assemble as part of an ultra high precision stereo comparator.

3. Test and Inspection Data

Procedure, techniques and equipment list required to certify elements, components, sub-assemblies and system fabricated as a result of this design effort.

4. Detailed Specifications

Ray traces, computer runs, materiels, coatings (transmitting and reflecting), illuminance and spectral characteristic estimates, design and notebook data, and performance data incidental to the effort as described herein.

of the parts, components and assemblies as designed and installed in or on the structure of the Stereo Comparator. The cost estimate will estimate labor and all materiel in detail and summarize on Form 633-4. This effort may be with the assistance of other [redacted] STAT approved suppliers.

10. Hardware Schedule

The vendor will, as a result of his design program, submit a proposed fabrication schedule for the hardware. This may be with the assistance of an [redacted] approved supplier if the capability for STAT fabrication does not exist with the designer.

5. Breadboard, Mock-ups

In the event the effort requires mock-up, or breadboard of any part or assembly to ascertain the practicability or proof of design, this hardware, including associated data or notes will be included as deliverable and its disposition will be determined [redacted] STAT

6. Technical Direction Mettings

As stated in the Technical Exhibit, concurrent with the optic system design, [redacted] engineering is developing the electro-mechanical STAT components for the instrument. Close technical liaison will require "on-the-spot" technical meetings. Please include in your quotation these anticipated visits.

7. Progress Reports

The vendor shall prepare and furnish monthly progress reports. Such reports shall contain a brief statement of the work completed during the preceding month and a description of work contemplated for the succeeding month. In addition, the reports shall contain a graph showing dollars expended on the ordinate versus time (in weeks) and percent of subcontract completion on the abscissa. Assuming progress payments are requested of the contractor, a forecast of the major elements of cost during the next reporting period will be required.

8. Briefing Materiel

Pertinent and descriptive technical materiel will be presented, per schedule, describing the optical system. This will be in the form of briefing boards (flip cards, 30" x 40") along with a short narrative for each.

A minimum number, no more than six, is requested.

9. Fixed Price Cost Estimate for Fabrication and Delivery of Hardware

During the course of this program, the vendor is required to develop a "best possible" estimate of the cost of the fabrication

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Subcontract No. ______________

Effective Date ______________

Contractual Provisions

(a) Definitions - As used in this subcontract, [redacted] STAT
[redacted] ARTICLE STAT
(S) means the items, parts, supplies, assemblies, data, information, drawings and services to be delivered to [redacted] hereunder; and Seller means STAT
the person accepting this subcontract.

(b) Changes - [redacted] may at any time by a written order, make changes STAT
within the general scope of this contract in any one or more of the following: (i) Drawings, designs or specifications where the articles are to be specially manufactured for [redacted] (ii) Method of shipment or packing; or (iii) Place of STAT
delivery. If any such changes causes an increase or decrease in the cost of or the time required for the performance of any part of this contract, an equitable adjustment shall be made in the contract price or delivery schedule, or both, provided that the Seller shall not be entitled to such equitable adjustment unless the Seller asserts his claim therefore within 10 days from his receipt of a given change. Nothing in this clause shall excuse the Seller from proceding with the contract as changed.

(c) Warranty - The subcontractor shall fully guarantee all items supplied for latent design defects for a period of twelve (12) months from final acceptance. The guarantee shall include all parts and labor. Unless expressly authorized, all repairs will be performed at site.

(d) Inspection - Articles purchased hereunder are subject to final inspection and approval at [redacted] plant, notwithstanding any other inspection, unless STAT
otherwise specifically stated on this contract. Neither compliance by Seller with instructions or suggestions by any employee of [redacted] payment of STAT
Seller's invoice for any article prior to final inspection shall be deemed an acceptance of the article or a waiver of the right of inspection or any other right herein reserved or relieve Seller of any obligation or liability under the terms and conditions of this contract. Defective articles will be rejected by NRI and the unit prices thereof will be debited against the invoice covering the shipment in which such products were included. Articles rejected will be held at Seller's risk and subject to Seller's disposal for a reasonable time, and if not disposed of by the Seller, will be sold or otherwise disposed of at the reasonable discretion of [redacted] for the Sellers account. STAT

(e) Patent Indemnity - Seller shall, at its expense, hold harmless and defend [redacted] its customers and all persons claiming under [redacted] against STAT
any suit or suits for the infringement of any patent, copyright or trademark, and shall indemnify the aforesaid parties against all damages, costs and expenses arising therefrom by reason of the manufacture, sale or the normal and intended use of the articles covered by this Contract [redacted] Agrees to STAT
Give Seller prompt notice in writing of any suit for infringement and such opportunity as is afforded by applicable laws, rules or regulations to participate in the defense thereof.

Subcontract No. ____________

Effective Date ____________

(f) Default - (a) [redacted] may by written notice of default to Seller terminate this contract or any part thereof if Seller (i) fails to deliver articles in accordance with the delivery dates specified, or (ii) so fails to make progress as to endanger performance of this contract or fails to comply with any of the other provisions of this contract and, in either case specified in (ii) does not cure such failure with a period of 10 days after receipt of notice from [redacted] specifying such failure. STAT STAT

(b) In the event [redacted] terminates this contract in whole or in part as provided in paragraph (a) of this clause, [redacted] may procure upon such terms as [redacted] may deem appropriate, articles similar to those so terminated and the Seller shall be liable to [redacted] for any excess costs occasioned [redacted] thereby, provided that the Seller shall continue the performance of this contract to the extent not terminated under the provisions of this clause. STAT STAT STAT STAT STAT

(c) Seller shall not be liable for excess costs when the failure of Seller to make deliveries in accordance with the delivery dates is due to causes beyond the control and without the fault or negligence of Seller. However, no cause shall relieve the Seller of liability unless Seller has notified [redacted] in writing of the existence of such cause within 10 days from the beginning thereof. STAT

(d) The rights of [redacted] under this clause shall not be exclusive and are in addition to other rights provided by law or this contract. STAT

(g) Cancellation - [redacted] at any time by written notice, may cancel this Contract or any part thereof at its convenience, in which event [redacted] shall be liable for the payment of reasonable cancellation charges which shall take into account among other things expenses already incurred and the Seller's actual liabilities against commitments made pursuant to this Contract. In no event, however, shall [redacted] be liable for cancellation charges which include anticipatory profits or which are in excess of the Contract price for cancelled articles. STAT STAT STAT

(h) General - (a) Assignment. Neither this contract nor any interest therein shall be assigned by the seller without the prior written consent of [redacted] except that monies due or to become due under this contract may be assigned upon written notice received and acknowledged by [redacted] provided that [redacted] shall have the right to ignore any assignment of monies which in any way, except for the obligation to pay the assignee, purports to alter or affect any right or duty of [redacted] or the Seller under this Contract. STAT STAT STAT STAT

(b) In the event of the appointment of a trustee, receiver or liquidator for all or a portion of Seller's property, or for any act of bankruptcy by the Seller as defined in Section 3 of the Bankruptcy Act, as amended, or for any voluntary petition in bankruptcy by the Seller, [redacted] may terminate the right of Seller to proceed with the further performance of this Contract without further obligation except that [redacted] shall be obligated to pay for any articles delivered and accepted prior to any of the foregoing occurrences. STAT STAT

Subcontract No. ____________

Effective Date ____________

(c) Note of Labor Disputes. Whenever an actual or potential labor dispute is delaying or threatens to delay the timely performance of this contract, Seller shall immediately give [redacted] notice thereof. Such notice shall include all relevant information relating to such dispute. STAT

(d) Price Omission. If the price for any article is omitted, such article shall be invoiced to [redacted] at the lowest prevailing market price, less maximum trade discounts. STAT

(i) Data - (a) The term "Subject Data" as used herein includes writings; sound recordings, pictorial reproductions, drawings or other graphical representations, and works of any similar nature (whether or not copyrighted) which are specified to be delivered under this contract. The term does not include financial reports, cost analyses, and other information incidental to contract administration.

(b) The Seller agrees to and does hereby grant to [redacted] and to its officers, agents, and employees acting within the scope of their official duties, a royalty-free, nonexclusive and irrevocable license throughout the world to publish, translate, reproduce, deliver, perform, dispose of, and to authorize others so to do, all Subject Data now or hereafter covered by copyright; provided, that with respect to the Subject Data now or hereafter covered by copywright and not originated in the performance of this contract, such license shall be only to the extent that the Seller, his employees, or any individual or concern specifically employed or assigned by the Seller to originate and prepare such Data under this contract, now has, or prior to completion or final settlement of this contract may acquire, the right to grant such license without becoming liable to pay compensation to others solely because of such grant. STAT

(c) The Seller shall exert all reasonable effort to advise [redacted] at the time of delivery of the Subject Data furnished under this contract, (i) of all invasions of the right of privacy contained therein and (ii) of all portions of such Data copied from work not composed or produced in the performance of this contract and not licensed under this clause. STAT

(d) The Seller shall report to [redacted] promptly and in reasonable written detail, each notice or claim of copyright infringement received by the Seller with respect to all Subject Data delivered under this contract. STAT

(e) Nothing contained in this clause shall imply a license to NRI under any patent or be construed as affecting the scope of any license or other right otherwise granted to [redacted] under any patent. STAT

(f) Subject to the provisions of (b) above and unless otherwise limited below, [redacted] may duplicate, use, and disclose in any manner and for any purpose whatsoever, and have others do so, all subject Data delivered under this contract. STAT

(g) The Seller recognizes that a foreign government with funds derived through the Mutual Security Program or otherwise through the United States Government and [redacted] may contract for property or services with respect STAT
to which the vendor may be liable to the Seller for charges for the use of Subject Data on account of such a contract. The Seller further recognizes that it is the policy of [redacted] and the Government not to pay in connection with STAT
its contracts, or to allow to be paid in connection with contracts made with funds derived through the Mutual Security Program or otherwise through the United States Government, charges for data which [redacted] and the Government STAT
have a right to use and disclose to others, or which is in the public domain, or with respect to which [redacted] and the Government have been placed in STAT
possession without restrictions upon its use and disclosure to others. This policy does not apply to reasonable reproduction, handling, mailing, and similar administrative costs incident to the furnishing of such data. In recognition of this policy, the Seller agrees to participate in and make appropriate arrangements for the exclusion of such charges from such contracts or for the refund of amounts received by the Seller with respect to any such charges not so excluded.

(h) Notwithstanding any provisions of this contract concerning inspection, and acceptance, [redacted] shall have the right at any time to modify, STAT
remove, obliterate or ignore any marking not authorized by the terms of this contract on any piece of Subject Data furnished under this contract.

(i) Data need not be furnished for standard commercial items or services which are normally or have been sold or offered to the public commercially by any supplier and which are incorporated as component parts in or to be used with the product or process being developed if in lieu thereof identification of source and characteristics (including performance specifications, when necessary) sufficient to enable [redacted] and the Government to procure STAT
the part or an adequate substitute, are furnished; and further, proprietary data need to be furnished for other items which were developed at private expense and previously sold or offered for sale, including minor modifications thereof, which are incorporated as component parts in or to be used with the product or process being developed, if in lieu thereof the Seller shall identify such other items and that "proprietary data" pertaining thereto which is necessary to enable reproduction or manufacture of the item or performance of the process. For the purpose of this clause "proprietary data" means data providing information concerning the details of a Contractor's secrets of manufacture, such as may be contained in but not limited to its manufacturing methods or processes, treatment and chemical composition of materials, plant layout and tooling, to the extent that such information is not disclosed by inspection or analysis of the product itself and to the extent that the Seller has protected such information from unrestricted use by others.

(j) Examination of Records - (a) The Seller agrees that the Comptroller of [redacted] and the Contracting Government Agency or any of his duly authorized STAT
representatives shall, until the expiration of three years after final payment

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under this contract, have access to and the right to examine any directly pertinent books, documents, papers and records of the Seller involving transactions related to this Contract.

(b) The Seller further agrees to include in all his subcontracts hereunder a provision to the effect that the subcontractor agrees that the Comptroller of [redacted] and the Contracting Government Agency or any of his duly authorized representatives shall, until the expiration of three years after final payment under the subcontract, have access to and the right to examine any directly pertinent books, documents, papers, and records of such subcontractor involving transactions related to the orders not exceeding $2,500. and (ii) subcontracts or purchase orders for public utility services at rates established for uniform applicability to the general public. STAT

(k) Patent Rights - (a) As used in this clause, the following terms shall have the meanings set forth below:

(i) The terms "Subject Invention" means any invention, improvement, or discovery (whether or not patentable) conceived or first actually reduced to practice either

(A) in the performance of the experimental, developmental, or research work called for or required under this contract; or

(B) in the performance of any experimental, developmental, or research work relating to the subject matter of this contract which was done upon an understanding in writing that a contract would be awarded; provided that the term "Subject Invention" shall not include any invention which is specifically identified and listed in the Schedule for the purpose of excluding it from the license granted by this clause.

(ii) The term "Technical Personnel" means any person employed by or working under contract with the Seller (other than a subcontractor whose responsibilities with respect to rights accruing to [redacted] or the Government in inventions arising under subcontracts are set forth in (g), (h), and (i) below) who, by reason of the nature of his duties in connection with the performance of this contract, would reasonably be expected to make inventions. STAT

(iii) The terms "subcontract" and "subcontractor" mean any subcontract or subcontractor of the Seller and any lower-tier subcontract or subcontractor under this contract.

(b) (1) The Seller agrees to and does hereby grant to [redacted] and STAT the Government an irrevocable, nonexclusive, nontransferable, and royalty-free license to practice, and cause to be practiced by or for [redacted] and the STAT United States Government, throughout the world, each Subject Invention in the manufacture, use and disposition according to law, of any article or material, and in the use of any method. Such license includes the practice of Subject Invention in the manufacture, use, and disposition of any article or material, in the use of any method, or in the performance of any service acquired by or for [redacted] and the Government or with funds derived through the STAT Mutual Security Program of the Government or otherwise through the Government. No license granted herein shall convey any right to [redacted] and the STAT Government to manufacture, have manufactured, or use any Subject Invention for the purpose of providing services or supplies to the general public in competition with the Seller or the Seller's Commercial licensees in the licensed fields.

(2) With respect to:

(i) any Subject Invention made by other than Technical Personnel;

(ii) any Subject Invention conceived prior to, but first actually reduced to practice in the course of, any of the experimental, developmental or research work specified in (a) (i) above; and

(iii) the practice of any Subject Invention in foreign countries; the obligation of the Seller to grant a license as provided in (b) (i) above, to convey title as procided in (d) (ii) (B) or (d) (iv) below, and to convey foreign rights as provided in (e) below, shall be limited to the extent of the Seller's right to grant the same without incurring any obligation to pay royalties or other compensation to others solely on account of said grant. Nothing contained in this Patent Rights clause shall be deemed to grant any license under any invention other than a Subject Invention.

(c) The Seller shall furnish to [redacted] the following information STAT and reports concerning Subject Inventions which reasonably appear to be patentable:

(i) a written disclosure promptly after conception or first actual reduction to practice of each such Invention together with a written statement specifying whether or not a United States patent application claiming the Invention has been or will be filed by or on behalf of the Seller;

Subcontract No. ______________

Effective Date ______________

(ii) interim reports at least every twelve months, commencing with the date of this contract, each listing all such Inventions conceived or first actually reduced to practice more than three months prior to the date of the report, and not listed on a prior interim report, or certifying that there are no such unreported Inventions; and

(iii) prior to final settlement of this contract, a final report listing all such Inventions including all those previously listed in interim reports.

(d) In connection with each Subject Invention referred to in (c) above, the Seller shall do the following:

(i) if the Seller specifies that a United States patent application claiming such Inventions will be filed, the Seller shall file or cause to be filed such application in due form and time; however, if the Seller, after having specified that such an application would be filed, decides not to file or cause to be filed said application, the Seller shall so notify [redacted] STAT
at the earliest practicable date and in any event not later than eight months after first publication, public use or sale.

(ii) if the Seller specifies that a United States patent application claiming such invention has not been filed and will not be filed (or having specified that such an application will be filed thereafter notifies [redacted] to the contrary), the Seller shall: STAT

(A) inform [redacted] in writing at the earliest practicable date of any publication of such Invention made by or known to the Seller or, where applicable, of any contemplated publication by the Seller, stating the date and identity of such publication or contemplated publication; and STAT

(B) convey to [redacted] the Sellers entire right, title, and interest in such Invention by delivering to [redacted] upon written request such duly executed instruments (prepared [redacted] or the Government) of assignment and application, and such other papers as are deemed necessary to vest in [redacted] the Seller's right, title, and interest aforesaid, and the right to apply for and prosecute patent applications covering such Invention throughout the world, subject, however, to the rights of the Seller in foreign applications as provided in (e) below, and subject further to the reservation of a non-exclusive and royalty-free license to the Seller (and to its existing and future associated and affiliated companies, if any, within the corporate structure of which the Seller is a part) STAT STAT STAT STAT which license shall be assignable to the successor of that part of the Seller's business to which such Invention pertains;

(iii) the Seller shall furnish promptly to [redacted] on request STAT an irrevocable power of attorney to inspect and make copies of each United States patent application filed by or on behalf of the Seller covering any such Invention;

(iv) in the event the Seller, or those other than [redacted] STAT deriving rights from the Seller, elects not to continue prosecution of any such United States patent application filed by or on behalf of the Seller, the Seller shall so notify [redacted] not less than sixty days before the expiration of the STAT response period and, upon written request, deliver to the Seller such duly executed instruments (prepared by [redacted] or by the Government) as are deemed STAT necessary to vest in [redacted] and the Government the Seller's entire right, title, STAT and interest in such Invention and the application, subject to the reservation as specified in (d) (ii) above; and

(v) the Seller shall deliver to [redacted] duly executed instru- STAT ments fully confirmatory of any license rights herein agreed to be granted to [redacted] or the Government. STAT

(e) The Seller, or those other than the Government deriving rights from the Seller, shall, as between the parties hereto, have the exclusive right to file applications on Subject Inventions in each foreign country within:

(i) nine months from the date a corresponding United States application is filed;

(ii) six months from date permission is granted to file foreign applications where such filing had been prohibited for security reasons; or

(iii) such longer period as may be approved [redacted] STAT

The Seller shall, upon written request, [redacted] or the STAT Government the Seller's entire right, title, and interest in each Subject Invention in each foreign country in which an application has not been filed within the time above specified, subject to the reservation of a non-exclusive and royalty-free license to the Seller together with the right of the Seller to grant sub-licenses, which license and right shall be assignable to the successor of that part of the Seller's business to which the Subject Invention pertains.

(f) If the Seller fails to deliver to [redacted] the interim reports STAT required by (c) (ii) above, or fails to furnish the written disclosures for all subject Inventions required by (c) (i) above shown to be due in accordance with any interim report delivered under (c) (ii) or otherwise known to be unreported, there shall be withheld from payment until the Seller shall have corrected such failures either ten percent (10%) of the amount of this contract, as from time to time amended, or five thousand dollars ($5, 000), whichever is less. After payment of eighty percent (80%) of the amount of this contract, as from time to time amended, payment shall be withheld until a reserve of either ten percent (10%), of such amount, or five thousand dollars ($5, 000), whichever is less, shall have been set aside, such reserve or balance thereof to be retained until the Seller shall have furnished to NRI:

(i) the final report required by (c) (iii) above;

(ii) written disclosures for all Subject Inventions required by (c) (i) above which are shown to be due in accordance with interim reports delivered under (c) (ii) above, or in accordance with such final reports, or are otherwise known to be unreported; and

(iii) the information as to any subcontractor required by (h) below.

The maximum amount which may be withheld under this paragraph (f) shall not exceed ten percent (10%) of the amount of this contract or five thousand dollars ($5, 000) whichever is less, and no amount shall be withheld under this paragraph (f) when the amount specified by this paragraph (f) is being withheld under other provisions of this contract. The withholding of any amount or subsequent payment thereof to the Seller shall not be construed as a waiver of any rights accruing [redacted] or the Government under this contract. STAT This paragraph (f) shall not be construed as requiring the Seller to withhold any amounts from a subcontractor to enforce compliance with the patent provisions of a subcontract.

(g) The Seller shall exert all reasonable effort in negotiating for the inclusion of a patent rights clause containing all the provisions of this Patent Rights clause except provisions (f) and (i) in any subcontract hereunder of three thousand dollars ($3, 000) or more having experimental, developmental, or research work as one of its purposes. In the event of refusal by a subcontractor to accept such a patent rights clause, the Seller shall not proceed with the subcontract without written authorization [redacted] STAT or unless there has been a waiver of the requirement as hereinafter provided. The Seller, if unable to comply with the requirement that such a patent rights clause be included in a subcontract after exerting all reasonable effort to do so, may submit [redacted] a written request for waiver or modification of such STAT requirement. If, within thirty-five (35) days after the receipt of such request, [redacted] does not mail or otherwise furnish the Seller's written denial of such STAT request or notification that [redacted] requests the Seller's cooperation with [redacted] or STATT the Government, which the Seller agrees to provide, in negotiating with the subcontractor for the acceptance of a suitable patent right clause, the requirements shall be deemed to have been waived by [redacted] as to all patent rights STAT provisions with respect to Subject Inventions, except such provisions, if any,

relating to the production or utilization of special nuclear material or atomic
energy. Such request shall specifically state that the Seller has used all
reasonable effort to comply with said requirement and shall cite the waiver
provision hereinabove set forth. The Seller is not required, when negotiating
with a subcontractor, to obtain in behalf [redacted] or the Government any rights STAT
in Subject Inventions other than as provided herein. However, the Seller is
not precluded from separately negotiating with a subcontractor for rights in
Subject Inventions for the Seller's own behalf, but any costs so incurred shall
not be considered as an allowable charge or cost under this contract. Reports,
instruments, and other information required to be furnished by a subcontractor
[redacted] under the provisions of such a patent right clause in a subcontract STAT
hereunder may, upon mutual consent of the Seller and the subcontractor (or by
direction [redacted] be furnished to the Seller for transmission [redacted] STAT

(h) The Seller shall, at the earliest practicable date, notify
[redacted] in writing of any subcontract containing one or more patent rights clauses; STAT
furnish [redacted] a copy of each such clauses; and notify [redacted] when such sub- STAT
contract is completed. It is understood that with respect to any subcontract
clause granting rights to [redacted] or the Government in Subject Inventions, [redacted] STAT
and the Government are third party beneficiaries, and the Seller hereby
assigns to [redacted] and the Government all rights that the Seller would have to STAT
enforce the subcontractor's obligations for the benefit of [redacted] and the STAT
Government with respect to Subject Inventions. If there are no subcontract
containing patent rights clauses, a negative report is required. The Seller
shall not be obligated to enforce the agreements of any subcontractor here-
under elating to the obligation of the subcontractor to [redacted] and the Government STAT
in regard to Subject Inventions.

(i) When the Seller shows that he has been delayed in the
performance of this contract by reason of the Seller's inability to obtain, in
accordance with the requirements of (g) above, the prescribed or other
authorized suitable patent rights clause from a qualified subcontractor for
any item or service required under this contract for which the Seller himself
does not have available facilities or qualified personnel, the Seller's
delivery dates shall be extended for a period of time equal to the duration
of such delay. Upon request of the Seller, [redacted] shall determine to what extent, STAT
if any, an additional extension of the delivery dates and increase in contract
prices based upon additional costs incurred by such delay are proper under
the circumstances; and the contract shall be modified accordingly.

(j) The Seller recognizes that a foreign Government with funds
derived through the Mutual Security Program or otherwise through the United
States Government and [redacted] may contract for property or services with respect STAT
to which the vendor may be liable to the Seller for royalties for the use of a
Subject Invention on account of such a contract. The Seller further recognizes
that it is the policy of [redacted] and the Government not to pay in connection made STAT
with its contracts, or to allow to be paid in connection with contracts made
with funds derived through the Mutual Security Program or otherwise through
the United States Government, charges for use of patents in which [redacted] and STAT

the Government holds a royalty-free license. In recognition of this policy, the Seller agrees to participate in and make appropriate arrangements for the exclusion of such charges from such contracts for the refund of amounts received by the Seller with respect to any such charges not so excluded.

(1) Filing of Patent Applications - (a) Before filing or causing to be filed a patent application disclosing any subject matter of this contract, which subject matter is classified "SECRET" or higher, the Seller shall, citing the thirty (30) day provision below, transmit the proposed application to [redacted] for determination whether, for reasons of national security, such application should be placed under an order of secrecy or sealed in accordance with the provisions of 35 U.S. Code 181-188 or the issuance of a patent should be otherwise delayed under pertinent statutes or regulations; and the Seller shall observe any instructions of [redacted] with respect to the manner of Delivery of the patent application to the U. S. Patent Office for filing, but the Seller shall not be denied the right to file such patent application. If [redacted] shall not have given any such instructions within thirty (30) days from the date of mailing or other transmittal of the proposed application, the Seller may file the application. STAT STAT STAT

(b) The Seller shall furnish to [redacted] at the time of or prior to the time when the Seller files or causes to be filed a patent application disclosing any subject matter of this contract, which subject matter is classified "CONFIDENTIAL," a copy of such application for determination whether, for reasons of national security, such application should be placed under an order of secrecy or the issuance of a patent should otherwise be delayed under pertinent statutes or regulations. STAT

(c) In filing any patent application coming within the scope of this clause, the Seller shall observe all applicable security regulations covering the transmission of classified subject matter.

[redacted] STAT

By ______________________ By ______________________

Date ______________________ Date ______________________

By ______________________

Date ______________________

COST AND PRICE ANALYSIS - RESEARCH AND DEVELOPMENT CONTRACTS

(This form is to be used in lieu of DD Form 633, as provided under ASPR 16-206. It will be executed and submitted with proposals in response to "Requests for Proposals," for the procurement of research and development services. If your cost accounting system does not permit analysis of costs as required, contact the purchasing office for further instructions.)

FORM APPROVED
BUDGET BUREAU NO. 22-R208

PURCHASE REQUEST NUMBER

NAME AND ADDRESS OF OFFEROR

TITLE OF PROJECT

DETAIL DESCRIPTION

1. DIRECT LABOR *(Specify)*	ESTIMATED HOURS	RATE /HOUR	TOTAL ESTIMATED COST *(Dollars)*
TOTAL DIRECT LABOR			

2. BURDEN *(Overhead - specify)* DEPARTMENT OR COST CENTER	BURDEN RATE	X BASE =	BURDEN *($)*	
TOTAL BURDEN				

3. DIRECT MATERIAL	EST COST *($)*	
TOTAL MATERIAL		
4. SPECIAL TESTING *(Including field work at Government installations)*		
TOTAL SPECIAL TESTING		
5. SPECIAL EQUIPMENT *(If direct charge - specify in Exhibit B, reverse)*		
6. TRAVEL *(If direct charge)*		
a. TRANSPORTATION		
b. PER DIEM OR SUBSISTENCE		
TOTAL TRAVEL		
7. CONSULTANTS *(Identity - purpose - rate)*		
TOTAL CONSULTANTS		
8. SUBCONTRACTS *(Specify in Exhibit A on reverse)*		
9. OTHER DIRECT COSTS *(Specify in Exhibit B on reverse - explain royalty costs, if any)*		
10. **TOTAL DIRECT COST AND BURDEN**		
11. GENERAL AND ADMINISTRATIVE EXPENSE *(Rate % of item nos.)*		
12. **TOTAL ESTIMATED COST**		
13. FIXED FEE OR PROFIT *(State basis for amount in proposal)*		
14. **TOTAL ESTIMATED COST AND FIXED FEE OR PROFIT**		

DD FORM 1 SEP 60 **633-4**

15. OVERHEAD RATE AND GENERAL AND ADMINISTRATIVE RATE INFORMATION		
A. GOVERNMENT AUDIT PERFORMED ☐ YES ☐ NO ☐ PENDING	DATE OF AUDIT	ACCOUNTING PERIOD COVERED
B. NAME AND ADDRESS OF GOVERNMENT AGENCY MAKING AUDIT		C. DO YOUR CONTRACTS PROVIDE NEGOTIATED OVERHEAD RATES *(ASPR 3-704)? (If yes, name Agency negotiating rates)*

D. *(If no Government rates have been established furnish the following information)*

DEPARTMENT OR COST CENTER	RATE	BASE	TOTAL INDIRECT EXPENSE POOL	BASE FOR TOTAL

16. EXHIBIT A - SUBCONTRACT INFORMATION ***(If more space needed, use blank sheets, identifying item number)***

NAME AND ADDRESS OF SUBCONTRACTOR(S)	SUBCONTRACTED WORK	SUBCONTRACT	
		TYPE	AMOUNT

17. EXHIBIT B - OTHER DIRECT COSTS ***(Specify. If more space needed, use blank sheets, identifying item number)***

CERTIFICATE

The labor rates and overhead costs are current and other estimated costs have been determined by generally accepted accounting principles. Bidder represents: (a) that he ☐ has, ☐ has not, employed or retained any company or person (other than a full-time bona fide employee working solely for the bidder) to solicit or secure his contract, and (b) that he ☐ has, ☐ has not, paid or agreed to pay to any company or person (other than a full-time bona fide employee working solely for the bidder) any fee, commission, percentage or brokerage fee, contingent upon or resulting from the award of this contract, and agrees to furnish information relating to (a) and (b) above, as requested by Contracting Officer. *(For interpretation of the representation, including the term "bona fide employee," see Code of Federal Regulations, Title 44, Part 150.)*

Number of contractor employees ☐ Over 500 ☐ Under 500

State incorporated in

DATE	SIGNATURE AND TITLE OF AUTHORIZED REPRESENTATIVE OF CONTRACTOR

OPTICAL SYSTEM

BIDDERS LIST

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